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MASTER PROJECT WORK

Planning flexible urban infrastructure to accommodate uncertainty in urban development

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Abstract

The planning and implementation of infrastructure modifications in urban areas, which have a long service life, can take many years. The reasons can be various, such as that the discussions and approval of the budget take a very long time or simply that there is no willingness to change. Also, after the implementation of the modification the needs and demands of the user and owner will change during the lifetime of the object. It is therefore difficult to design these infrastructures in such a way that they provide an adequate level of service over the entire lifetime. There are considerable uncertainties in the parameters that influence this planning over the entire life cycle. These uncertainties can be mitigated by implementing a flexible design. This flexible design gives a certain tolerance for these uncertainties by offering the possibility of easier adaptation in the future, but whether this pays off is not clear.

In the case study of this project work we focus on the bike and road infrastructure network in the city of Uster. At the moment, there are traffic problems mainly due to the fact that the railway crossing in the city centre is closed during rush hour for about 40 minutes per hour. This leads to congested roads in the entire city and therefore the canton of Zürich and Uster are discussing about the construction of a road ring on the west side of the city. Another possible future adaption of the infrastructure network is an underpass in the city centre.

The Real Option Methodology is a good approach to evaluate such problems. In our work we considered scenarios with different initial designs such as doing nothing, build a two or four lane road ring and a design which can be expanded from two to four lanes easily if it is needed. In our project, we compare those designs to determine the best investment in infrastructure at the present time. The goal is to minimise the total costs, which include costs of the owner and user. To estimate the future changes in users some key parameters need to be taken into account. In this project work the considered parameters for the future change in bike and car user are population growth, expansion of the hospital, implementation of a new underground train station, the increase in autonomous vehicles and the increase in hybrid bikes. The uncertainty of all these parameters are modelled with a Monte Carlo Simulation. Based on the number of future users, the costs for each possible design can be calculated and compared. The results show that a normal design of the road ring with two lanes, as it has already been discussed for Uster, combined with an underpass in the city centre would be the most beneficial initial design.

Zusammenfassung

Die Planung und Durchführung von Infrastrukturmodifikationen in städtischen Gebieten, welche eine lange Nutzungsdauer haben, können viele Jahre in Anspruch nehmen. Die Gründe dafür können vielfältig sein, z.B. die Diskussionen und die Freigabe des Budgets können sehr lange dauern oder das einfach nur die Bereitschaft zur Veränderung nicht vorhanden ist. Auch nach der Implementierung der neuen Infrastruktur können sich die Bedürfnisse und Anforderungen des Benutzers und Eigentümers während der Lebensdauer des Objekts ändern. Es ist daher schwierig, diese Infrastrukturen so zu gestalten, dass sie über die gesamte Lebensdauer ein angemessenes Leistungsniveau bieten. Die Parameter, die diese Planung über den gesamten Lebenszyklus beeinflussen, sind mit erheblichen Unsicherheiten behaftet. Diese Unsicherheiten können durch die Implementierung eines flexiblen Designs gemildert werden. Dieses flexible Design gibt eine gewisse Toleranz für diese Unsicherheiten, indem es die Möglichkeit einer Anpassung an der Infrastruktur in der Zukunft bietet, aber ob sich dies auszahlt ist nicht klar.

In der Fallstudie dieser Projektarbeit konzentrieren wir uns auf das Rad- und Strasseninfrastrukturnetz in der Stadt Uster. Derzeit gibt es vor allem Verkehrsprobleme, weil der Bahnübergang im Stadtzentrum während der Hauptverkehrszeit für etwa 40 Minuten pro Stunde geschlossen ist. Dies führt zu überlasteten Strassen in der ganzen Stadt und deshalb diskutieren der Kanton Zürich und die Stadt Uster über den Bau einer Umfahrung im Westen der Stadt. Eine weitere mögliche zukünftige Anpassung des Infrastrukturnetzes ist eine Unterführung im Stadtzentrum.

Die Real Option Methodik ist ein guter Ansatz, um solche Probleme zu bewerten. In unserer Arbeit haben wir Szenarien mit unterschiedlichen Ausgangskonzepten betrachtet, wie z.B. nichts tun, eine zwei- oder vierspurigen Umfahrung bauen und ein Design, das bei Bedarf leicht von zwei auf vier Spuren erweitert werden kann. In unserem Projekt vergleichen wir diese Designs, um die derzeit besten Investitionen in die Infrastruktur zu ermitteln. Ziel ist es, die Gesamtkosten, zu denen die Kosten des Eigentümers und des Nutzers gehören, zu minimieren. Um die zukünftige Veränderung der Nutzer abzuschätzen, müssen einige Schlüsselparameter berücksichtigt werden. In dieser Projektarbeit werden die Parameter für den zukünftigen Wandel von Fahrrad und PKW-Nutzern anhand des Bevölkerungswachstum, des Ausbaus des Krankenhauses, der Errichtung eines neuen Untergrund-Bahnhofs, der Zunahme autonomer Fahrzeuge und der Zunahme von Elektrofahrrädern betrachtet. Die Unsicherheit all dieser Parameter wird mit der Monte-Carlo-Simulation modelliert. Anhand der Anzahl der zukünftigen Nutzer werden die Kosten für jedes mögliche Design berechnet und verglichen. Daraus ergibt sich, dass eine normale Gestaltung der Umfahrung mit zwei Fahrspuren, wie sie bereits für Uster diskutiert wurde, in Kombination mit einer Unterführung im Stadtzentrum das vorteilhafteste initiale Design wäre.

Acknowledgments

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1 Introduction

Infrastructure exists for a very long time. When building road and bike infrastructure usually the current needs or the most likely future scenarios are taken into account, but in the lifespan of an infrastructure the needs of the users and owner can change drastically due to many influence factors like new technologies, other adapted infrastructure or growth in population. Often it is uncertain if demand even rises or drops. This can lead to infrastructure which is over or under dimensioned in the future and as well to very high costs for either the owner or the infrastructure user.

To handle this challenge the Real Option Methodology can be applied with different initial designs to evaluate which initial investment has the best net benefit over a considered time period. In order to do these calculations, estimates about certain key parameters need to be done to simulate the future changes. The results of the methodology depend highly on the selection and modelling of the key parameters and therefore they need to be defined very carefully. To compare the benefits of different designs, they first need to be defined. In addition to initial designs which exist for the entire life span also flexible designs can be considered. They can be adapted in the future when specific defined triggering conditions are reached. Through the application of the methodology it is possible to evaluate if the additional initial costs for a flexible design are worth the investment.

In our project work we are considering the road and bike infrastructure network in the city of Uster and evaluate different design scenarios to prepare the city in the best possible way to the future changes in bike and car users.

2 Background

The world is changing all the time due to the technical development and changes in the needs of the population. This makes it crucial to develop a way to take these uncertainties into consideration when making decisions. The Real Option Methodology is a procedure to take the uncertainty in the future into account to evaluate initial designs in infrastructure. Future changes can have different reasons like economic issues, technological improvements, population growth or political decisions. (Martani 2019)

The literature review in Table 1 shows the authors, year of publication, topic, modelled variable and key parameters of examples from different applications and studies about the Real Option Methodology in the past. The methodology can be used to solve a variety of problems. In all of them the methodology has been applied on a single object to identify if a flexible design is worth the higher initial investment. But there are, as far as we know, no applications of this methodology to analyse a network of several elements which are connected to each other. This is what we are going to evaluate in our project work. We want to apply the Real Option Methodology to an infrastructure network and make proposals how to design the network at the moment by taking possible future changes into account.

Table 1: Literature Review

Authors (Year)	**Topic**	**Modelled variable**	**Key parameters**
Esders, Della Morte, and Adey (2015)	A Methodology to Ensure the Consideration of Flexibility and Robustness in the Selection of Facility Renewal Projects	Net benefit of barrack configuration	- No. of soldiers in a company in the barracks - No. of female soldiers in the barracks
Fawcett et al. (2014)	Cost and Environmental Evaluation of Flexible Strategies for a Highway Construction Project under Traffic Growth Uncertainty	Economic and environmental costs of highway pavements	- Traffic growth
Martani, Cattrinussi, and Adey (2017)	A new process for the evaluation of the net-benefit of flexible ground-floor ceiling in the face of use transition uncertainty	Net benefit of building	- Use transitions
Martani et al. (2016)	Design with uncertainty: the role of future options for infrastructure integration	Net benefit of building	- Gas and electricity price - Demand for heating and cooling loads - Coefficient of GSHP performance (COP).

Elvarsson (2018)	Flexible parking infrastructures: The use of Real Option to account for future mobility uncertainty	Net benefit of design	- Parking demand
Schärer (2018)	Flexibility in parking spaces to take into consideration the future need of electrical charge facilities	Net benefit of design	- Market share of EVs - Costs of charging stations - Behaviour of users

3 Methodology

3.1 Real Option Methodology

An appropriate approach to take future development into consideration is the Real Option Methodology. It can be used to evaluate the optimal initial investment to reach the best result over the entire lifetime of the objects. The Real Option Methodology can be subdivided into nine steps which are presented in Table 2 (Martani 2019).

Table 2: Nine steps of Real Option Methodology based on Martani (2019)

Step	Description
1	**Define stakeholders and required Level of Service (LOS) of infrastructure network**
	In the first step it needs to be defined what is expected from the infrastructure. This includes the definition of the scope, stakeholders and Level of Service.
2	**Identify key parameters**
	The values of key parameters have a considerable effect on the infrastructure and the LOS provided. In this step these parameters need to be identified and decided which parameters can be neglected and which have a higher impact on the analysed infrastructure.
3	**Identify the uncertainty over the key parameters**
	The parameters which have been identified in step two need to be analysed and their uncertainty have to be determined by taking into consideration past data, future predictions and expert opinions. The uncertainty needs to be expressed in a probability that a certain scenario will occur.
4	**Model the uncertainty over the key parameters**
	Based on the identified uncertainties in step three, they need to be modelled over the entire time period. In our case this will be done by using the Monte Carlo Simulation (see chapter 3.1.1). With this step, it is possible to make future predictions of the key parameters based on probabilities of occurrence.

5	**Develop static system model**
	Based on the assumption of a precise estimation of the key parameters a function has to be formulated to evaluate the infrastructure. This formula depends on the key parameters and can for example have the goal to maximise net benefit or minimise the total costs.
6	**Develop dynamic system model**
	The inclusion of the variation over time of the key parameters in the static system model leads to the dynamic system model.
7	**Identify possible future changes in infrastructure network**
	Determine possibilities to adapt the infrastructure network in the future to the new needs. Identify the triggering possibilities like an expansion of the infrastructure to increase the benefit / reduce the costs of the network.
8	**Define possible initial designs and scenarios**
	Find an appropriate initial design which is flexible and can easy be adapted to the future changes. But also take other scenarios which include fixed designs into consideration in order to compare if they are better or worse than a flexible initial design.
9	**Estimate the net benefit of all initial designs considering possible future changes**
	Simulate the different scenarios with the varying parameters which have been analysed and estimate the costs and benefits of each design.

In chapter 6 all these nine steps will be applied to the specific case study and gone through step by step. The application of this appropriate methodology gives us a tool to solve the prevailing problem.

3.1.1 Monte Carlo Simulation

The Monte Carlo Simulation is used to model uncertain future scenarios with a probabilistic approach. Based on the most likely scenarios 1000 simulations are done to simulate all possible scenarios.

Through random sampling the Monte Carlo Method can simulate different scenarios. “It is based on the principle that an event with a X % probability to happen, has the same likelihood to occur than one of the real numbers between 1 and X to be extracted from a random sample of real numbers from 1 to 100.” (Martani 2019)

4 Case Study

Uster is a city in the canton of Zürich and has approximately 35’000 habitants (Stadt Uster 2017). Uster has already traffic problems, mainly because of the fact that during the rush hours the railway crossing in the city centre is closed for approximately 40 minutes every hour. This leads to long waiting times and congestion on all nearly located roads. Additionally, the future growth in Uster is very uncertain, as there are for example plans for a hospital extension and considerations for a new underground train station, which both would affect the amount of traffic in the city. These are just two factors of many others which influence the future of Uster. In our project work we focus on the change in the road and bike infrastructure network of the city which can be seen in Figure 1.

These infrastructure changes are due to the change in demand and therefore an expansion of the network might be required. In Uster there is a discussion about the construction of a road ring on the west side of the city. The road ring would cross the railway track with an overpass. Another possible change in the future is an underpass in the city centre.

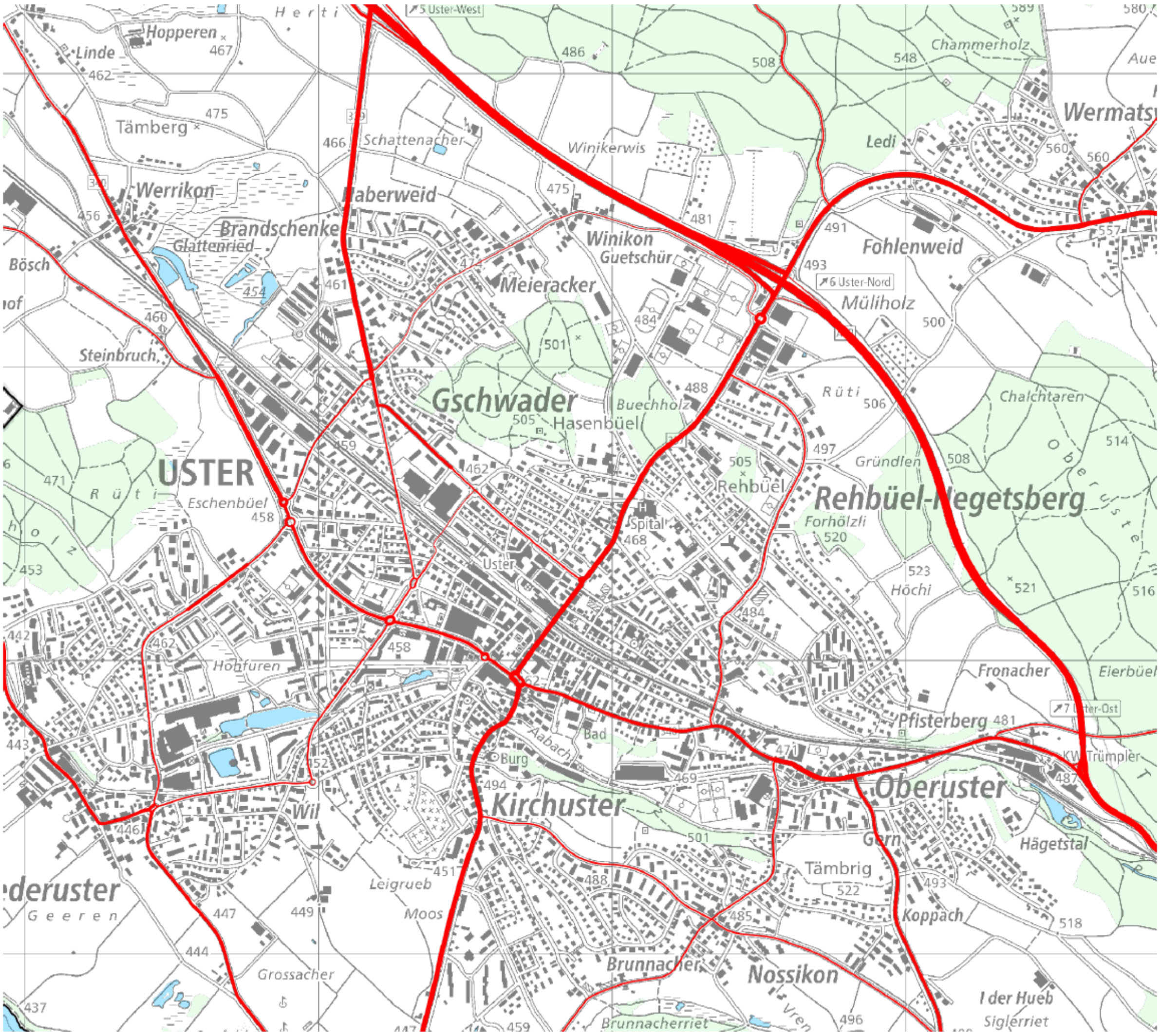

Figure 1: Road network of Uster (Kanton Zürich 2019)

5 Goals

In this chapter an overview over the goals of this project work are given. The main goal is to find the best strategy with an initial design for the road and bike network in Uster which guarantees an optimal infrastructure over the considered time period of 50 years by taking the possible future changes in needs of the users and owner into consideration.

In order to find the optimal strategy, the following goals have to be satisfied in the best possible way:

- Minimise total costs and maximise net benefit for user and owner
    - Minimise user costs
        - Minimise safety costs / Maximise level of safety
        - Minimise costs of lost travel time
    - Minimise owner costs
        - Minimise intervention costs
        - Minimise costs for initial design
        - Minimise costs for expansion of the infrastructure network
- Maximise provided Level of Service
- Prepare the network optimal for future changes in needs of the user

6 Application of the Real Option Methodology

6.1 Define stakeholders and required Level of Service (LOS) of infrastructure network

To define the Level of Service, first it needs to be carried out which stakeholders are included in the analysis of the present project work.

6.1.1 Stakeholders

The stakeholders for the road and bike infrastructure network are the owner, the user, the directly affected public (DAP) and the indirectly affected public (IAP). The owner, which is in this case the ASTRA for the canton roads and the municipality for all the other ones. They are responsible for the maintenance and any kind of modification of the roads. The users are people who drive on this road system either with a car or a bicycle. The directly affected public are people that live near the roads and are exposed to the emissions like noise and smell of the traffic. The indirectly affected public are people far away from the road but who are still affected by effects like a changing climate due to the traffic emissions.(Adey and Martani 2018)

The owner provides the money for all the interventions and modifications. He also makes decisions and finally chooses what will be actually done and therefore he is a key stakeholder and will be taken into consideration. The user is the most affected stakeholder and for this reason he is also indispensable to be considered.

As already mentioned, the DAP are all the people that live close to the road network but compared to the more directly involved stakeholders such as the owner and the user, the effects on DAP are not big enough to have a focus on these. We decided therefore to focus on the owner and the user in this report and not to include the DAP. If the work is to be continued or looked at it in a more detailed way, the DAP would of course have to be included.

All people who are not living anywhere near the infrastructure but are affected by the climatic changes are the so called IAP. The IAP is not taken into consideration in this report. The reason is due to a similar fact as for the DAP, they are excluded because it is a first investigation in the topic of flexibility on infrastructure networks and therefore the scope is reduced to the two main stakeholders.

An overview of the included and excluded stakeholders is given in Table 3.

Table 3: Overview of stakeholders

Stakeholders	**Definition**	**Consideration**	
		Include	**Exclude**
Owner	Organisation or person who is responsible for maintenance and any kind of modification.	The owner provides the money for the interventions and makes decisions.	
User	Persons who are using the roads, like car drivers and cyclists.	The users are the most affected stakeholders.	
Directly affected public	People that live close to the roads and are subjected to emissions like noise and smell.		The size of the impacts does not justify the consideration of the DAP compared to the effects on the user and owner.
Indirectly affected public	People not living nearby but who are affected by the use of the road due to the traffic (basically everybody).		The impact on the IAP is extremely small and in this case for our study negligible.

6.1.2 Level of Service (LOS)

For the road network a Level of Service (LOS) can be defined, which has a state from A to D. The best Level of Service is an A and D is the worst one. The Level of Service describes the possibility for traffic system users to travel through the considered section of traffic infrastructure in a certain amount of time.

Table 4: Definition of Level of Service (LOS)

LOS	**Definition**
A	Free-flow, traffic with different users unaffected by the presence of others in the same traffic stream
B	Stable traffic flow, with a high degree of freedom to choose the speed and operating conditions but with some influence from other users
C	Unstable flow, where speed and freedom of movement are restricted and comfort and convenience have diminished, although the flow remains stable.
D	Breakdown flow, in which the amount of traffic reaches a point at which the amount cannot be served anymore. It is characterized by stop-and-go waves, poor travel times, low comfort and convenience, and increased accident exposure.

6.1.3 Cost Structure

There are different types of costs for the different stakeholders, which will be considered. These costs are the basis for the cost / benefit calculations in our simulation.

6.1.3.1 Owner

There are two different costs which are associated with the owner. At first the construction costs for any additional infrastructure design which will be presented in Chapter 6.8. The second costs are the intervention costs, i.e. the cost to plan and execute maintenance interventions (repair and renewal of infrastructure) in order to provide an adequate level of service at any time. These intervention costs could be further subdivided into labour, material and equipment costs. In this report it is more useful and sufficient detailed to keep the subtasks together and only have one estimate for the intervention costs. Nevertheless, a differentiation needs to be done between interventions on roads and bridges. (Adey and Martani 2018)

In a talk with Marcel Burkhalter from the ETH Zürich (Institut für Bau- und Infrastrukturmanagement), we figured out the yearly maintenance intervention costs over the service life. For roads we assume 5 CHF/m^2 per year and for the more complex bridge structure we figured out intervention costs in the range between 30 and 40 CHF per square meter per year. In order to have one concrete price we assume the average value of 35 CHF/m^2 per year for our calculations. All the owner costs are summarized in Table 5.

Table 5: Owner costs

Stakeholder	Owner	
Cost type	Intervention costs	
Infrastructure type	Road	Bridge
Costs in CHF/m²/year	5	35

6.1.3.2 User

Not only the owner has infrastructure costs but also the users of the road infrastructure have costs while using it, for example with a traffic jam comes some lost travel time which causes costs. Therefore, the users have different grouped costs, which are safety, operation efficiency, operation quality and environment preservation.

The safety costs for the user can be subdivided into property damage, injury and death costs. In detail the property damage can appear as the damaged or destroyed cars because an accident happened. To get a cost estimation for the property damage some assumptions had to be made. First the number of involved cars in an accident is assumed to be between one and two. Second there are by far more slightly than seriously injured people due to car accidents, from which it is assumed that most of the involved cars are not damaged completely and the costs therefore are not extremely high (Bundesamt für Statistik 2018). Third, the average car on swiss roads is 8.4 years old and its value has therefore already decreased heavily (Launaz 2018). Based on the mentioned references in the end, the property damage costs are estimated to be 15’000 CHF per accident.

The costs for the death of a person is based on an analysis of the value of a statistical life and it comes from the ASTRA. In this case a fatal accident with the death of a person is set to 3’700’000 CHF (Tagesanzeiger 2016).

The monetary costs associated with the injury of a person rest on a study which shows that the costs for a seriously injured person is 12 % and the costs for a slightly injured person 1 % of the value of a statistical life (swov.nl 2017). When now this numbers are connected to the number of people which were seriously injured and slightly injured from Bundesamt für Statistik (2018), an injury of a person is 3 % of the value of a statistical life, which is 110’000 CHF.

The operation efficiency, operation quality and environment preservation cost will be taken together for simplification reasons in the calculations. The most important part are the costs for the travel time lost as a part of the operation efficiency. The travel time can be split into the cost indicators ‘work time wasted’ and ‘leisure time wasted’, because the cost values are not the same. For this case it was decided to take them into account as one single value as similar done in the reference papers. By multiplying the mean of the lost travel time per car estimated in the research papers from M. Keller and Wüthrich (2016, 2012) with the average occupancy of a car of 1.6 people per car results in costs of 55 CHF/h (Bundesamt für Statistik 2017). This number has been verified in a consultation with Dr. Claudio Martani from ETH Zürich (Institut für Bau- und Infrastrukturmanagement). The user costs are summarised in Table 6.

Table 6: User costs

Stakeholder	User					
Cost type	Safety			Operation efficiency	Operation Quality	Environment preservation
Cost indicator	Property damage	Injury	Death	Work and leisure time		
Costs units	CHF/Accident	CHF/Injured Person	CHF/Causality	CHF/Hour		
Cost amount	15’000	110’000	3’700’000	55		

6.2 Identify key parameters

Many different parameters have an influence on the number of cars and bikes using the infrastructure network. Based on the fact that only a few of those have a non-neglectable influence, the focus in this project work is on these key parameters. Considering the uncertainty of the parameters, it does not make sense to include parameters which have an absolute number which is a lot smaller than the uncertainty of others.

Based on research in the internet on existing projects and past evolutions we decided to implement the following key parameters which influence the amount of bike and car users in the infrastructure network of Uster.

- Change in population
- Implementation of a new underground train station
- Expansion of the existing hospital
- Increase in use of autonomous vehicles
- Increase in use of hybrid bikes

In the following chapter 6.3 the values for the defined key parameters are established.

6.3 Identify the uncertainty over the key parameters

In this chapter the uncertainties over the key parameters which have been defined in the previous chapter are determined based on research and past evolutions.

6.3.1 Change in population

The current population in Uster is approximately 35’000 habitants (Stadt Uster 2017). In Figure 2 it is shown how the population in Uster has changed since 1990. Assuming that the growth follows the same trend line, the population will increase by 500 people every year. The current amount of habitants leads to a traffic on the network of approximately 16’000 daily cars (Kanton Zürich 2019). Based on this numbers it can be calculated that additional 500 people lead to an increase of 235 daily traffic. Therefore the daily car traffic increases yearly by 375 users because on average the occupancy rate is 1.6 people per car (Bundesamt für Statistik 2017).

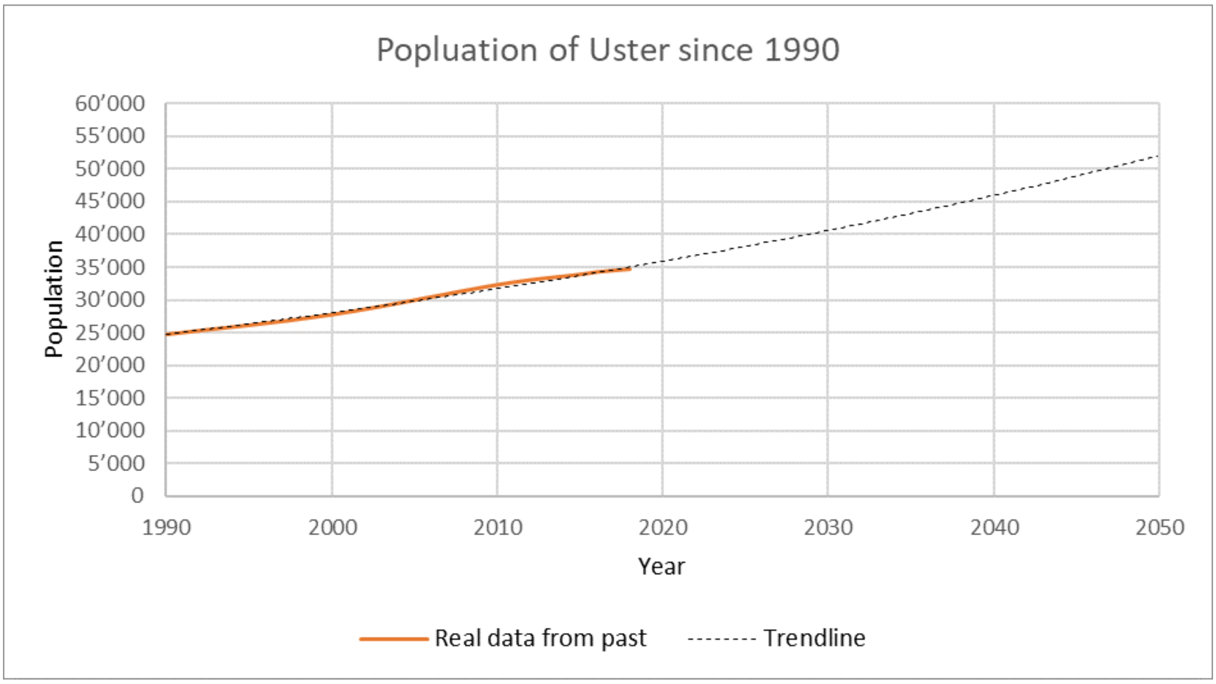

Figure 2: Population of Uster since 1990 (Statistisches Amt Zürich 2019)

Villiger (2013) observed that 10 % of all travelled ways are done by bikes. Furthermore, we assume that everyone who uses a bike makes two ways because one need to go somewhere and return later. With these assumptions it can be calculate that 500 additional habitants lead to an increase of yearly 100 daily bike users.

The standard deviation of the growing population is assumed to increase with the time, starting with a value of 5 % and after 50 years it counts 15 %.

6.3.2 Implementation of a new underground train station

Uster is located near to the city of Zürich. Therefore, many people work in the city of Zürich and live in Uster and need to commute daily between those two cities. To solve traffic problems on the roads in and around Uster, there are considerations about building a new underground train station (Jeanneret-Gris 2014). Through an implementation of a new railway station and the included expansion of the train services would lead to a more attractive public transport and therefore to a reduction of car traffic in the city. At the same time the amount of people using bikes would increase because bikes are an appropriate vehicle to reach the train station which is located in the city centre. The implementation of an underground train station is very uncertain because there are at the moment no concrete plans by the public authorities. This is why we assumed the probability of the construction of this underground station to be very uncertain in the upcoming years. After 20 years we assumed that the train station is implemented with a probability of only 5 %, also because the planning and building of such an underground would take a long time. With an increase of time the probability rises and at the end of our time horizon, after 50 years, we assumed that the train station exists with a probability of 50 %.

Once the underground train station is implemented, it is also uncertain how many users will change from using cars to train and how many of them will come by bike to the train station. At the moment approximately 28’000 passengers using the train station in Uster every day. (Kanton Zürich 2018d) According to Donzé (2015) the number of passengers using the train station of Uster will increase with 40 % until 2030 with the expansion of the railway network between Uster and Zurich. Therefore, there will be about 10’000 more passengers every day. Considering the fact that about the half of the increase is coming from the growth of population. 15 years after the implementation of the underground station we consider an average of 5’000 new daily users of the train station, which have been using a car before. In the first years after the implementation will change more people to the public transport and afterwards it will flatten out and then increase linearly over the years. In Figure 3 one can see the mean change in car users after the implementation of the new underground train station.

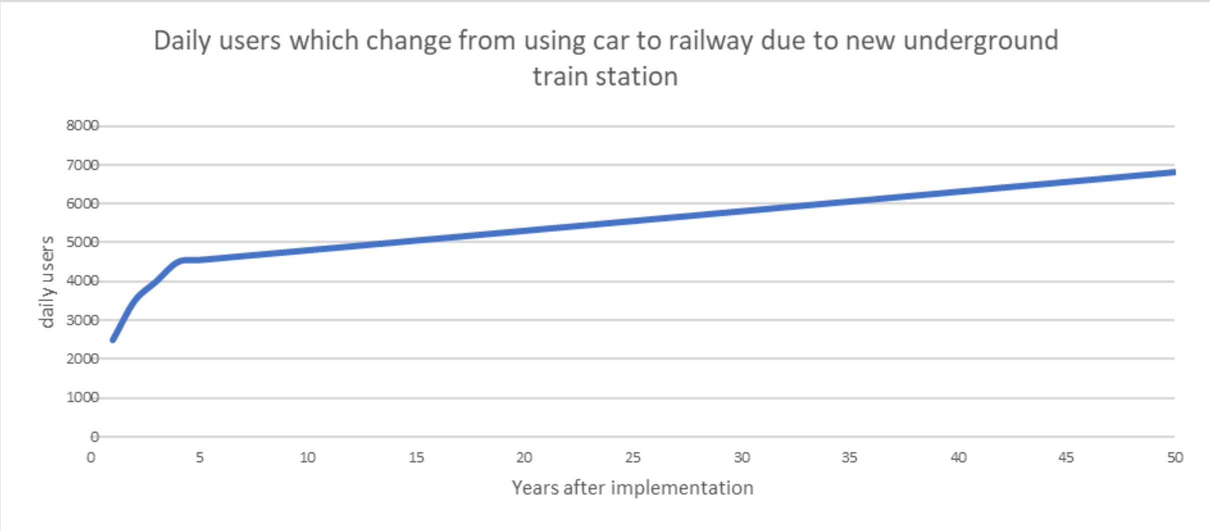

Figure 3: Daily users which change from using car to train due to implementation of new underground train station

Based on the fact that not all users travel by bike to the railway station, the amount of additional bike users is smaller than the decrease of car users. But it follows the same trend. Taking into consideration that Uster is a quite small city and therefore the distance to the railway station is quite short compared to bigger cities, more people will take the bike instead of using a bus. Therefore, we assume 15 years after the implementation of the new underground train station an increase in daily bike users of about 4’000.

6.3.3 Expansion of the existing hospital

The hospital in Uster has already planned to build an expansion in the upcoming years. In the beginning of 2019, the hospital got the building permit. The opening is expected for the year 2025 (Spital Uster 2019). This very clear timetable makes it more predictable to see when it will be finished. Therefore, the standard deviation for the simulation of the uncertainty is very small. The highest probability is that the expansion will be implemented in year 2025 and from 2028 on we assume that it is sure that it will be opened.

The higher uncertainty is in the number of additional car users due to the hospital expansion. The additional bike users are not taken into consideration because they are neglectable small based on the assumption that the patients and employees mainly travel by car or public transport to the hospital. The expansion increases the amount of hospital beds by 60 and therefore the number of stationary patients by 30 % (Spital Uster 2018). Before the expansion the hospital has 1283 employees and treats approximately 11’000 stationary patients per year. Therefore, the additional yearly patients will be 3’300, what leads to 9 more stationary patients per day. All of the patients come and leave once and therefore have two ways which leads to a mean of 18 car users per day. With the assumptions of an increase in employees of also 30 % and on average one visitor per bed and day, with the expansion there will be 390 additional employees and 60 visitors daily. According to aargaumobil (2019) 50 % of the visitors and employees come by car to the hospital. The visitors and the employees do also travel two ways and therefore there will be an increase in daily traffic of approximately 470 users. Because not all of the patients and employees will be there from the first year after the implementation, we assumed that the number will increase from 400 to 470 daily traffic users from year 1 to 8 and afterwards it is assumed to be constant.

6.3.4 Increase in use of autonomous vehicles

It is quite sure that autonomous vehicles will be implemented in the future, but it is very uncertain what effect it will have on the number of cars on the road network. Roland Siegwart from ETH Zürich expects the commercial implementation of autonomous vehicles to start between 2025 and 2030 (Schoop 2015). According to Raths (2015) autonomous vehicles will first be used only on highways and it will take until 2035 or even 2045 until they can be used in city centres. Therefore, we assume that until 2030 there will be an increase of cars due to the benefits of higher degree of automatization but considering the fact that they are not driving autonomous there will probably be no decrease in daily traffic until 2030.

Autonomous vehicles induce empty drives in order to pick up the passengers. In an extreme case that can be up to 1.5 empty drives per person and day. This would lead to an increase in traffic of about 50 %. Additionally, autonomous vehicles might lead to an increase of car users of 10 % because it is a new kind of means of transport. This would lead to a total increase of up to 60 %. (Meyer et al. 2016)

In their journal article Bösch, Ciari, and Axhausen (2016) mention that their study showed that a reduction of 90 % of the current vehicles would still be enough to serve the demand, because the cars could be shared easier when using totally autonomous vehicles. It could almost be used as a new kind of public transport. Having in mind that this is the theoretical reduction and it is very possible that the people will not share cars in such a high degree, we searched more references with a less extreme value. Zhang et al. (2015) write in their study that a reduction of the traffic of 60 % due to autonomous vehicles is appropriate.

Based on all those references we assume that autonomous vehicles can either lead to an increase or decrease of 60 % of the current daily users. These two possibilities and their corresponding mean are shown in Figure 4.

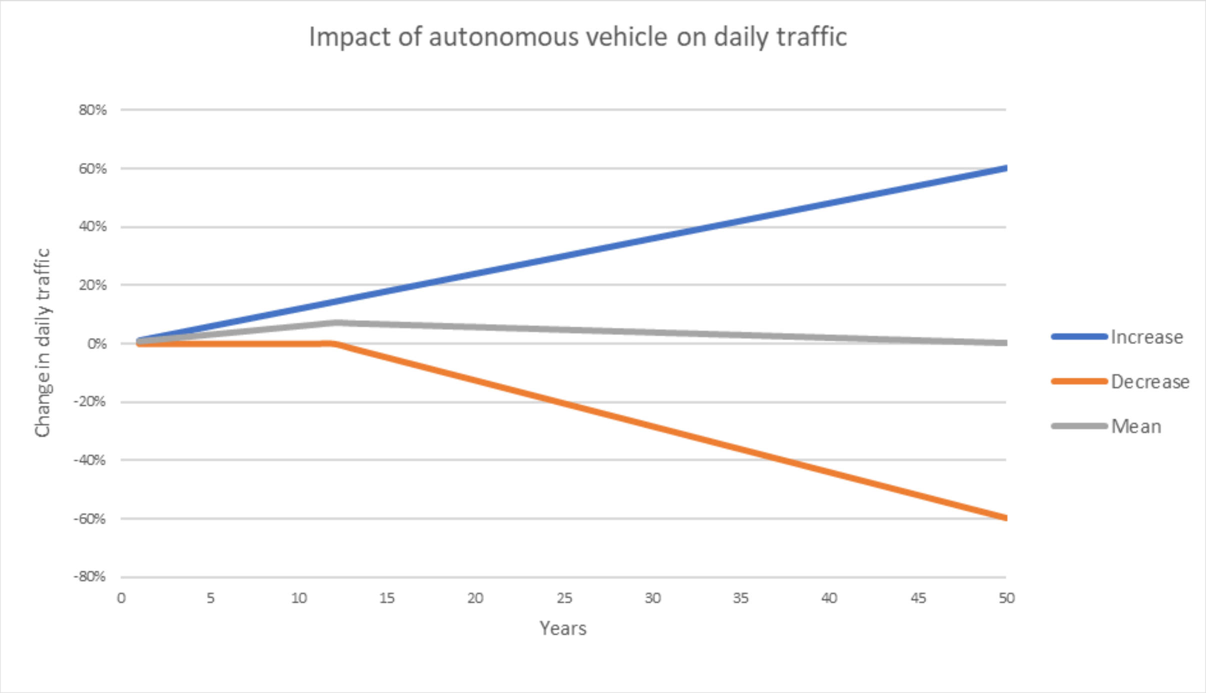

Figure 4: Impact of autonomous vehicles on daily traffic

6.3.5 Increase in use of hybrid bikes

More than 30 % of the new sold bikes in 2018 have been hybrid bikes (Schweizer Fachstelle für Velo und E-Bike 2019). By analysing the trend of the last years, it is recognisable that the driven cycling kilometres increase with approximately 2 % yearly. Therefore, we assume that the increase in daily users is also 2 % every year. According to Biedermann et al. (2017) 5 % of the population using bikes every day which leads based on the current population of 35’000 habitants to 1’750 daily bike users.

6.4 Model the uncertainty over the key parameters

In a next step the identified uncertainties over the key parameters in chapter 6.3 are implemented in a Monte Carlo Simulation in Excel. For all key parameters, distributions and simulations have been set up. As an example, the distribution of the additional daily car users due to the growth in population is shown in Figure 5. To make the report easier to read only one distribution table is presented here. The other distributions are attached in the appendices in chapter 11. Because of the fact that the distribution table is very large, in Figure 6 a zoom of the first 5 years of Figure 5 is shown. The x-axis includes all the years and the most likely evolution (mu) with the corresponding standard deviation (sigma) which has been explained in chapter 6.3. On the y-axis all possible variabilities in car users are displayed. The probability of each variability in users for every year is normal distributed and can be read out of the table. The red area in Figure 5 shows the variation of users with a probability of 99 %. 1000 simulations with random numbers have been done in order to get a stable result of the variation in users. For the new underground train station and the hospital two different distributions and therefore also two simulations have been done. The first to estimate in which year it will be implemented and then a second to evaluate the variability in user in the years after the implementation.

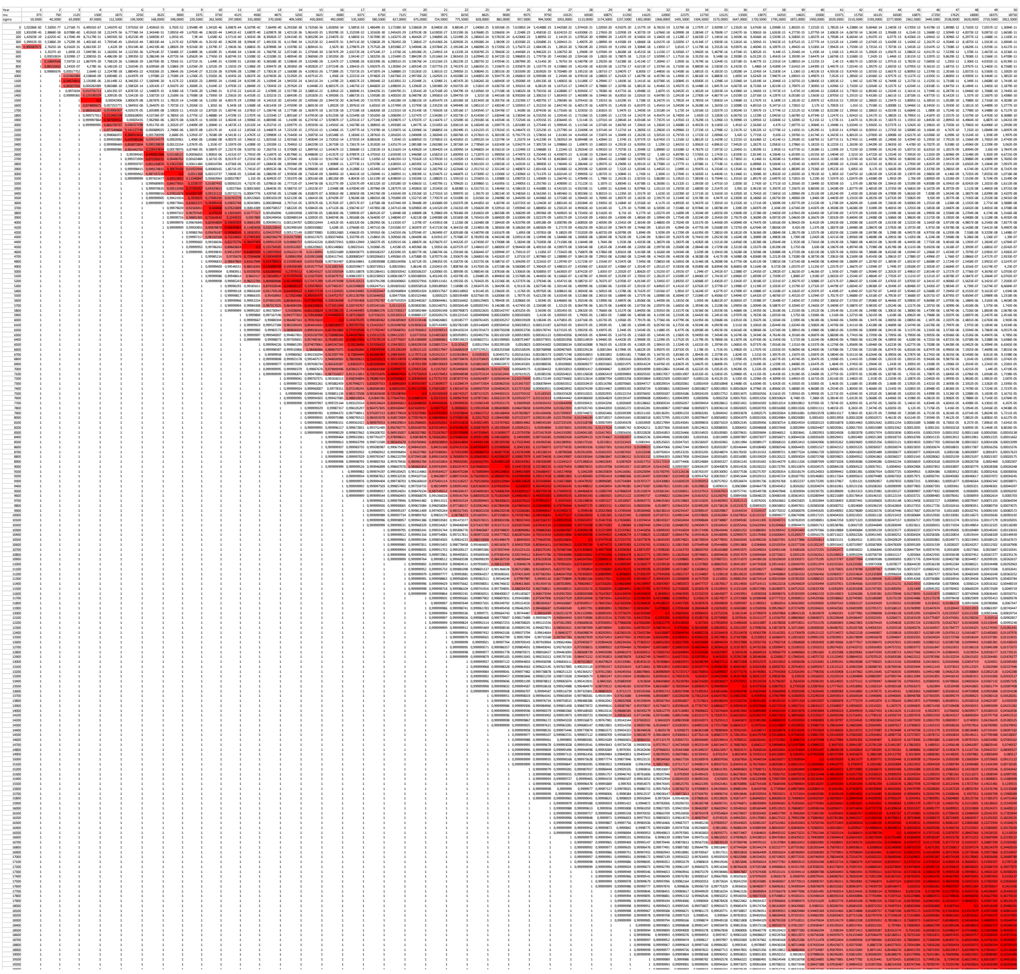

Figure 5: Distribution of additional daily car users due to growth in population

Year	1	2	3	4	5
mu	375	750	1125	1500	1875
sigma	19,5000	40,5000	63,0000	87,0000	112,5000
0	1,02286E-82	7,3205E-77	1,2716E-71	6,49501E-67	1,14507E-62
100	1,83109E-45	2,8868E-58	8,0788E-60	1,45261E-58	2,21247E-56
200	1,42503E-19	2,6225E-42	4,1704E-49	8,71179E-51	1,94592E-50
300	5,99932E-05	5,5386E-29	1,7529E-39	1,40216E-43	7,79354E-45
400	0,900087671	2,7625E-18	6,0162E-31	6,06233E-37	1,422E-39
500	1	3,3537E-10	1,693E-23	7,04978E-31	1,18265E-34
600	1	0,00010624	3,9299E-17	2,20855E-25	4,48619E-30
700	1	0,10849568	7,5972E-12	1,86797E-20	7,76812E-26
800	1	0,89150432	1,2432E-07	4,278E-16	6,14613E-22
900	1	0,99989376	0,00017752	2,664E-12	2,22478E-18
1000	1	1	0,02362084	4,53864E-09	3,69048E-15
1100	1	1	0,34574811	2,13589E-06	2,81149E-12
1200	1	1	0,88307036	0,000282089	9,86588E-10
1300	1	1	0,9972634	0,010756713	1,60135E-07
1400	1	1	0,99999365	0,125190329	1,20953E-05
1500	1	1	1	0,5	0,00042906
1600	1	1	1	0,874809671	0,007253771
1700	1	1	1	0,989243287	0,059906907
1800	1	1	1	0,999717911	0,252492538
1900	1	1	1	0,999997864	0,587929552
2000	1	1	1	0,999999995	0,866739737
2100	1	1	1	1	0,977249868
2200	1	1	1	1	0,998066972
2300	1	1	1	1	0,999920883
2400	1	1	1	1	0,999998469
2500	1	1	1	1	0,999999986
2600	1	1	1	1	1
2700	1	1	1	1	1

Figure 6: First 5 years of distribution of additional daily car users due to growth in population

The total number of daily traffic users is the sum of the initial users and the variability of all simulations for each of the possible future changes. The total number of additional daily traffic users after 50 years is shown in a cumulative graph for cars in Figure 7 and for bikes in Figure 8. The median of daily user after 50 years is 42’508 for cars and 12’328 for bikes.

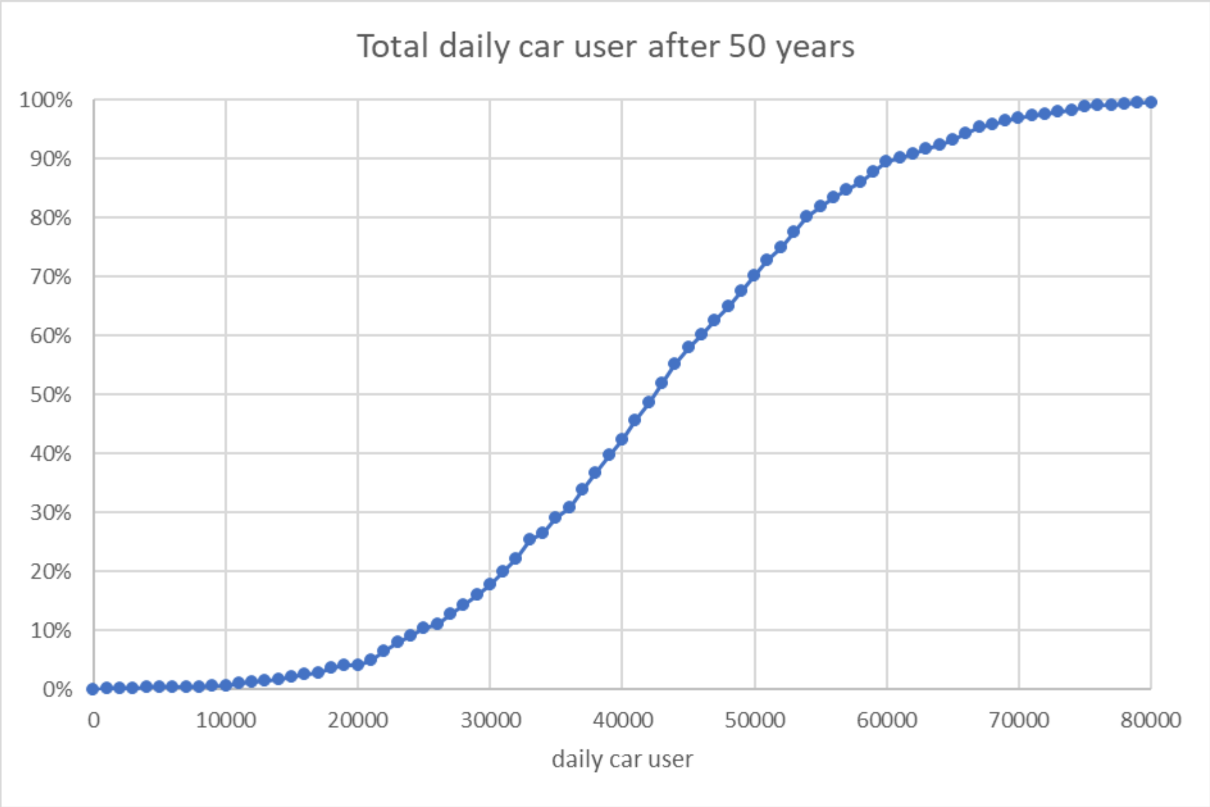

Figure 7: Cumulative graph of number of total daily car user after 50 years (1000 iterations)

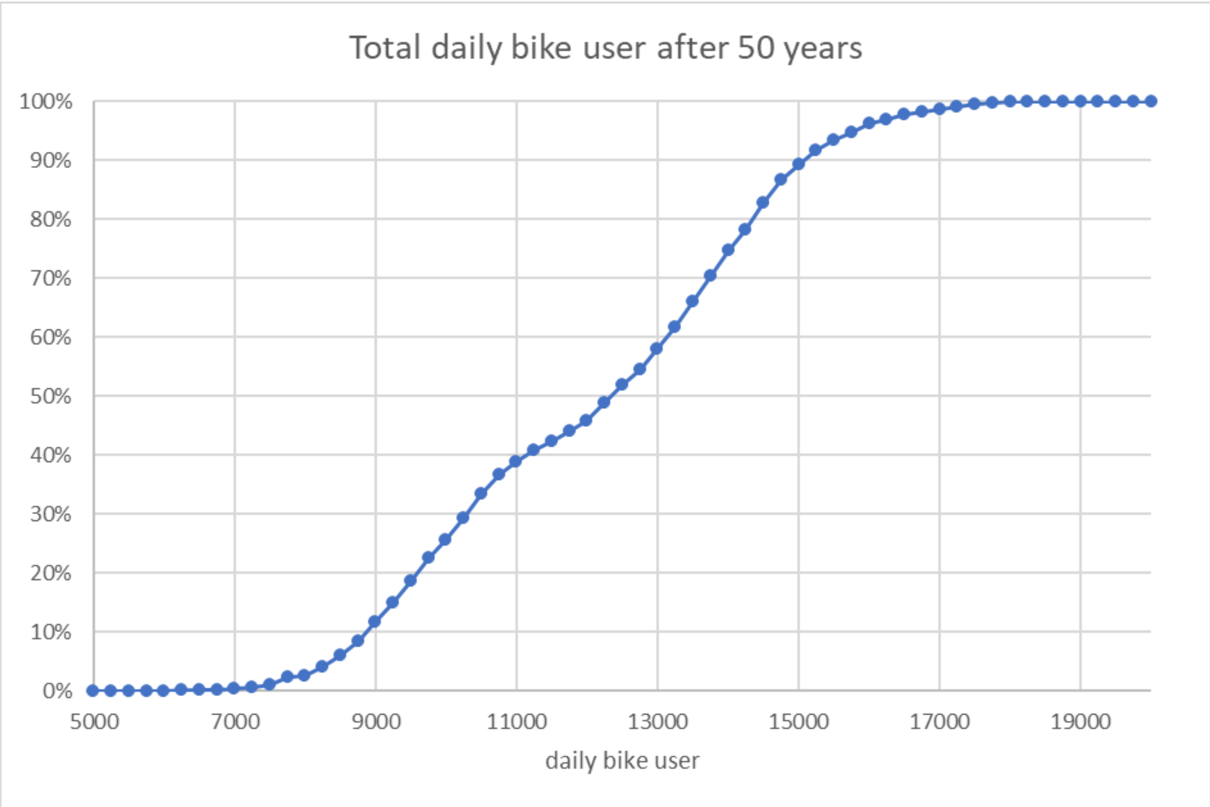

Figure 8: Cumulative graph of number of total daily bike user after 50 years (1000 iterations)

6.5 Develop static system model

Based on the defined goals in chapter 5 and the results of the simulations of the uncertainties of the key parameters, a static model has been developed. The formula is subdivided into owner costs and separate user costs for cars and bikes. All of these costs are first calculated for themselves and then added together to get the total costs. The goal is always to minimise the total costs to evaluate which scenario is the best for the infrastructure network.

6.5.1 Main formula

$$\mathrm{Min}[C_{\mathrm{Tot}}] = \mathrm{Min}\left[C_{\mathrm{Owner}} + C_{\mathrm{User,Car}} + C_{\mathrm{User,Bik}}\right] \quad (1)$$

$C_{\mathrm{Tot}} =$ Total costs of infrastructure network over T years

$C_{\mathrm{Owner}} =$ Total owner costs of infrastructure network over T years

$C_{\mathrm{User,Car}} =$ Total user costs for cars over T years

$C_{\mathrm{User,Bik}} =$ Total user costs for bikes over T years

In the main formula (1) the sum of the costs for the stakeholders, which are defined in chapter 6.1.1, is minimized. Because of the fact that we do not have any revenues in our calculation, minimising the costs is equivalent to maximising the net benefit.

6.5.2 Formula owner costs

$$C_{\mathrm{Owner}} = C_{\mathrm{Ini}} + \sum_{t=0}^{T}(C_{\mathrm{Int,t}} + \delta_t \cdot C_{\mathrm{Ext}}) \quad (2)$$

$C_{\mathrm{Owner}} =$ Total owner costs of infrastructure network over T years

$C_{\mathrm{Ini}} =$ Initial design costs of the owner

$C_{\mathrm{Int,t}} =$ Intervention costs of the owner in year t

$\delta_t =$ Delta Dirac function $\rightarrow$ equals one in the triggering year, zero in the other years

$C_{\mathrm{Ext}} =$ Costs of the owner for extension of infrastructure / triggering costs

Formula (2) shows the calculation of the owner costs. These costs include the initial design costs which incur only once in the beginning, the yearly intervention costs and the extension costs which need to be paid if the design gets triggered.

6.5.3 Formula user costs cars

$$C_{User,Car} = \sum_{t=0}^{T} (C_{Saf,Car,t} + C_{TT,Car,t}) \tag{3}$$

$C_{User,Car}$ = Total user costs for cars over T years

$C_{Saf,Car,t}$ = Total safety costs of the car users in year t

$C_{TT,Car,t}$ = Total costs of lost travel time of the car users in year t

The user costs in formula (3) include the yearly costs for safety and lost travel time.

Safety Costs

$$C_{Saf,Car,t} = S_{Car,t} \cdot P_{Acc,Car,t} \cdot C_{Acc} \tag{4}$$

$C_{Saf,Car,t}$ = Total safety costs of the car users in year t

$S_{Car,t}$ = Total car users in year t

$P_{Acc,Car,t}$ = Probability of occurrence of a car accident in year t, depends on capacity of network

C_{Acc} = Costs of an accident per car user

The safety costs are the product of the number of car users, the probability of an accident and the corresponding costs for an accident, which depends on the type of accident.

Costs of lost travel time

$$C_{TT,Car,t} = S_{Car,t} \cdot T_{lost,Car,t} \cdot C_{time} \tag{5}$$

$C_{TT,Car,t}$ = Total costs of lost travel time of the car users in year t

$S_{Car,t}$ = Total car users in year t

$T_{lost,Car,t}$ = Lost time in year t per car user on network, depending on capacity of network

C_{time} = Costs for lost time per user and hour

The costs for the lost travel time are calculated with formula (5). The number of car users gets multiplied with the lost time per year and the costs for a lost hour.

Number of users

$$S_{Car,t} = S_{Car,0} + S_{Pop,Car,t} + S_{Tra,Car,t} + S_{Hos,Car,t} + S_{Aut,Car,t} \qquad (6)$$

$S_{Car,t}$ = Total car users in year t

$S_{Car,0}$ = Initial car users in year 0

$S_{Pop,Car,t}$ = Variability in car users due to growth in population in year t

$S_{Tra,Car,t}$ = Variability in car users due to new underground train station in year t

$S_{Hos,Car,t}$ = Variability in car users due to new hospital in year t

$S_{Aut,Car,t}$ = Variability in car users due to increasing use of autonomous cars in year t

The number of car users can be calculated by formula (6) which is the summation of the variability in users of all considered future changes which impact the traffic on the network.

6.5.4 Formula user costs bikes:

$$C_{User,Bik} = \sum_{t=0}^{T} (C_{Saf,Bik,t} + C_{TT,Bik,t}) \qquad (7)$$

$C_{User,Bik}$ = Total user costs for bikes over T years

$C_{Saf,Bik,t}$ = Total safety costs of the bike users in year t

$C_{TT,Bik,t}$ = Total costs of lost travel time of the bike users in year t

Similar to the user costs for cars in formula (3), the user costs for bikes are calculated with formula (7) shown above. It includes the yearly safety and lost travel time costs.

Safety Costs

$$C_{Saf,Bik,t} = S_{Bik,t} \cdot P_{Acc,Bik,t} \cdot C_{Acc} \qquad (8)$$

$C_{Saf,Bik,t}$ = Total safety costs of the bike users in year t

$S_{Bik,t}$ = Total bike users in year t

$P_{Acc,Bik,t}$ = Probability of occurrence of a bike accident in year t, depends on capacity of network

C_{Acc} = Costs of an accident per bike user

The formula for the safety costs of bikes (8) is almost equal to the calculation of the corresponding costs for cars.

Costs of lost travel time

$$C_{TT,Bik,t} = S_{Bik,t} \cdot T_{lost,Bik,t} \cdot C_{time} \quad (9)$$

$C_{TT,Bik,t}$ = Total costs of lost travel time of the bike users in year t

$S_{Bik,t}$ = Total bike users in year t

$T_{lost,Bik,t}$ = Lost time in year t per bike user on network, depending on capacity of network

C_{time} = Costs for lost time per user and hour

The costs for the lost travel time of bikes is shown in formula (9) and includes the number of bike users, the lost time in hours and the costs per lost hour. The costs are calculated per year.

Number of users

$$S_{Bik,t} = S_{Bik,0} + S_{Pop,Bik,t} + S_{Tra,Bik,t} + S_{Hyb,Bik,t} \quad (10)$$

$S_{Bik,t}$ = Total bike users in year t

$S_{Bik,0}$ = Initial bike users in year 0

$S_{Pop,Bik,t}$ = Variability in bike users due to growth in population in year t

$S_{Tra,Bik,t}$ = Variability in bike users due to new underground train station in year t

$S_{Hyb,Bik,t}$ = Variability in bike users due to increasing use of hybrid bikes in year t

The total number of bike users is calculated with formula (10). The variability of users due to the population growth, the new train station and the increase in hybrid bikes is added to the initial bike users to get the total number of bike users per year.

6.6 Develop dynamic system model

The variation of the key parameters which have been defined and simulated in the chapters 6.2 to 6.4 is included in the static model of the previous chapter 6.5. This leads to a dynamic model which is set up for a time period of 50 years.

6.7 Identify possible future changes in infrastructure network

In order to adapt the road and bike network of Uster to an increase in traffic, a road ring on the west side of the city can be built. The road ring connects the Winterthurerstrasse with the Zürichstrasse and crosses the railway track with an overpass (orange road in Figure 9). The total length of the ring is 1150 metre, which contains a 680 metre long road section and a bridge with a length of 470 metre. This leads to an increase of capacity in the network because more lanes are available and the long waiting times at the railway crossing in the city centre can be reduced due to the overpass which is part of the road ring.

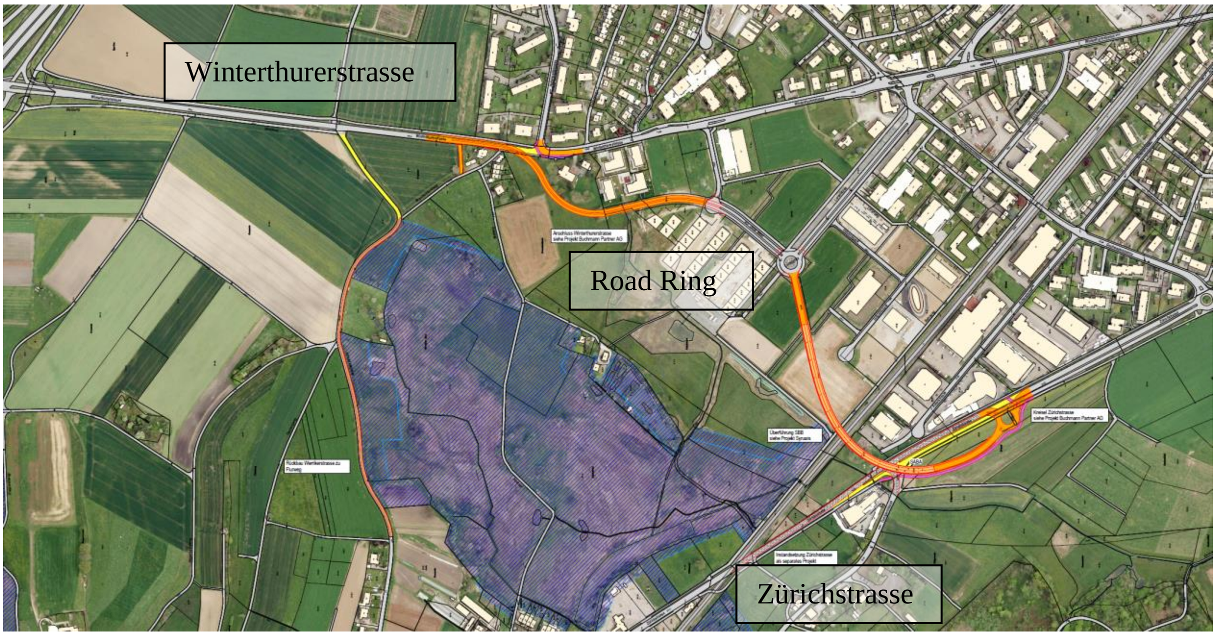

Figure 9: Map of the road ring around Uster (Tiefbauamt Kanton Zürich 2019)

Another possible change in the future is an underpass in the city centre to reduce the waiting time at the railway crossing. Because it is not sure if this underpass will be built and when, we consider the different scenarios which are described in the following chapter 6.8 with the underpass and without it in order to compare the results independently from the fact if the underpass will be built or not.

6.8 Define possible initial designs and scenarios

In our project work we consider different scenarios which are shown in Table 7.

Table 7: Overview different strategies

Strategy	**Initial Design**	**Initial Costs [CHF]**	**Possible extension / triggering**	**Extension costs [CHF]**
Do Nothing	The infrastructure remains as it is.	-	-	-
Normal Design	Design the road ring with two car lanes.	21 Mio (2’600 CHF/m²)	-	-
Flexible Design	Design the road ring with two car lanes and the possibility to expand it.	30 Mio (3’700 CHF/m²)	Add additional lanes for cars or bikes	8 Mio (1’000 CHF/m²)
Maximum Design	Design the road ring with four car lanes.	35.5 Mio (2’200 CHF/m²)	-	-
Underpass	All four designs above are also considered with an implemented underpass in the city centre.	24.5 Mio	-	-

6.8.1 Do Nothing

The basic strategy is to do nothing during the entire time period of 50 years. This will lead to an increase in user costs due to more traffic which cause more accidents and lost travel time. The construction costs will remain zero because there is no initial design or expansion of the network.

6.8.2 Normal Design

The second possibility is to build the road ring west in the way the canton of Zürich has planned it (see Figure 10). This means the ring has a width of 7 meter with one mixed bike and car lane in each direction. The costs for the Normal Design are calculated by the canton of Zürich and account for 21 million swiss francs (Tiefbauamt Kanton Zürich 2019). Dividing this number by length and width leads to 2’600 CHF/m^2 initial construction costs.

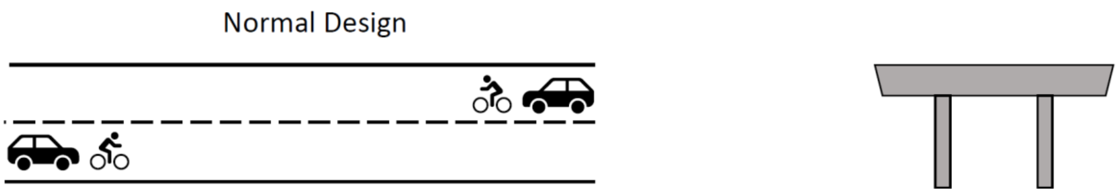

Figure 10: Normal Design of road ring

6.8.3 Flexible Design

The Flexible Design has a similar initial design as the Normal Design, but the basic structure is designed for more loads. This makes it possible to expand the road ring to a width of 14 meters. The expanded road ring can either be used as a 4-lane road or a 3-lane road with a separate cycling path. The initial design and the possible expansions are shown in Figure 11.

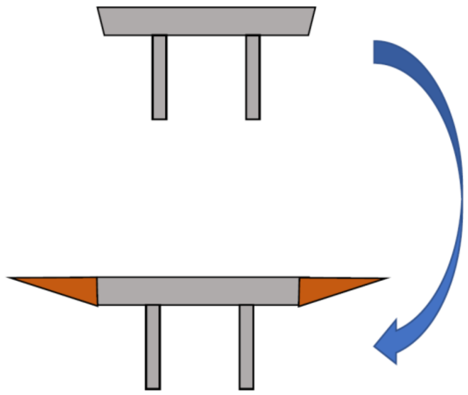

Figure 11: Flexible Design the road ring with expansion possibilities

For the estimation of costs, we consider in consultation with Marcel Burkhalter from the ETH Zürich (Institut für Bau- und Infrastrukturmanagement), the fact that around 60 % of the costs for the Maximum Design are related to the elements of the basic structure and assume that those costs only need to be paid for the initial design. The other 40 % are related to the width and therefore need to be paid for the initial construction and expansion of the road ring. This results in initial costs of 30 million swiss francs and expansion costs of additional 8 million swiss francs, which have to be paid when the triggering condition is reached, and the expansion of the road ring is built. Expressing these values in square meters the initial design costs 3’700 CHF/m^2 and the expansion 1’000 CHF/m^2.

6.8.4 Maximum Design

As shown in Figure 12 the last possibility is to build the road ring with a width of 14 meters and 4 lanes in the beginning even if it is not needed at that point in time. With the assumption of approximately 30 % fix costs of the Normal Design, the Maximum Design costs 2’200 CHF/m^2 and therefore 35.5 million swiss francs in total.

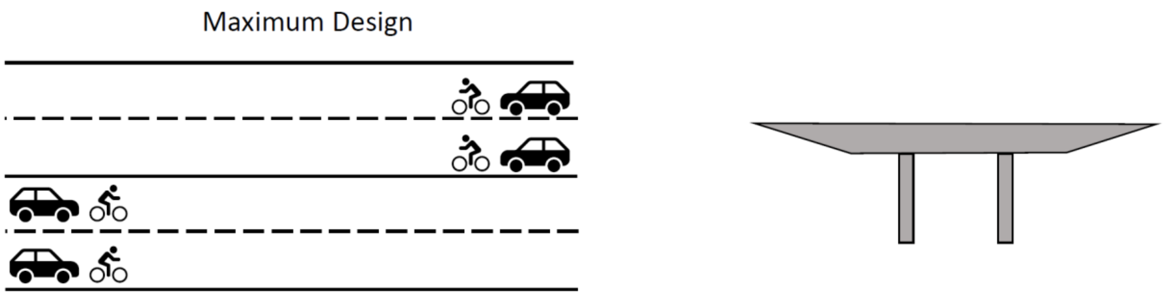

Figure 12: Maximum Design of road ring

6.8.5 Underpass

In order to reduce the long waiting times at the railway crossing in the city centre, Uster considers an implementation of an underpass. The costs of this underpass are estimated to be 24.5 million swiss francs including all surrounding work (Bornhauser and Baumberger 2012). In our work all scenarios (Do Nothing, Normal Design, Flexible Design and Maximum Design) are either evaluated with and without the underpass.

6.9 Estimate the net benefit of all initial designs considering possible future changes

6.9.1 Assumptions

To do all the simulations and calculations a lot of assumptions have to be made. These assumptions were needed to calculate the appropriate costs for the owner and the user in the different years over a time horizon of 50 years. In order to compare all scenarios on the same cost level, the first assumption is the discount rate of 3 %.

6.9.1.1 Owner costs

All the different scenarios in chapter 6.8 are based on the same infrastructure network. The only thing which is different is the implementation of the road ring. Therefore, only the owner costs of the road ring are taken into consideration for the cost calculation because the others are identical. As mentioned in chapter 6.1.3.1 the intervention costs are 5 CHF per square metre for roads and 35 CHF per square metre for the bridge. These prices combined with the different lengths of the sections from chapter 6.7 lead to a yearly square metre price of 17.26 CHF.

Because of the long planning of such infrastructures it is assumed that the initial construction costs are incurred in year 5.

6.9.1.2 User costs

Safety

One part of the user costs are the safety costs, which contains the property damage, injury and death costs. The monetization has already been discussed in chapter 6.1.3.2 but the probability of those incidents is depending on different factors.

For cars the total driven person kilometre per day are 34’568’400 (Kanton Zürich 2018b). This makes a total person kilometre per year of 12.6 billion kilometre. In the canton of Zürich, the number of property damages was 9’808 in the year 2018 and therefore the probability for a property damage can be calculated to $7.76 \cdot 10^{-7}$ property damages per driven kilometre. With the same calculations and the values for injuries of 1’414 and death of 9, the probabilities are $1.12 \cdot 10^{-7}$ injuries per driven kilometre and $7.13 \cdot 10^{-10}$ deaths per driven kilometre. (Kantonspolizei Zürich 2019)

On average every person in the canton of Zurich covers daily a distance of 35 kilometres and 9 % of this distance is done by bike (Kanton Zürich 2018c). In total live 1’498’641 people in the canton (Statistisches Amt Kanton Zürich and Zürcher Kantonalbank 2018). Multiplying these numbers with each other leads to a total person bike kilometre per day of 4’720’719.

The costs of property damage of bikes are so small that they are neglectable. The injured people on a bike in the traffic in year 2018 were 1’022 and 6 person died (Kantonspolizei Zürich 2019). The resulting probabilities for injuries and death on a bike are $5.93 \cdot 10^{-7}$ and $3.48 \cdot 10^{-9}$ per driven kilometre.

In Table 8 all probabilities of accidents per driven car and bike kilometre are shown.

Table 8: Probabilities of an accident

	Property damage	**Injury**	**Death**
Probability per driven km car	$7.76 \cdot 10^{-7}$	$1.12 \cdot 10^{-7}$	$7.13 \cdot 10^{-10}$
Probability per driven km bike		$5.93 \cdot 10^{-7}$	$3.48 \cdot 10^{-9}$

The probability of an accident and the degree of capacity utilisation are linked through the diagram from Zhou and Sisiopiku (1997) in Figure 13. In our case study we do not take into consideration the v/c ratios under 0.5 because they almost never exist on our network. As a simplification we assume the curve to be linear between v/c 0.5 to 0.9. This leads to an increase of accidents of 10 % for every 10 % higher degree of capacity utilisation. Moreover, the assumption was made that separate car and bike lanes reduce to probability of an accident to 80 % of the initial value.

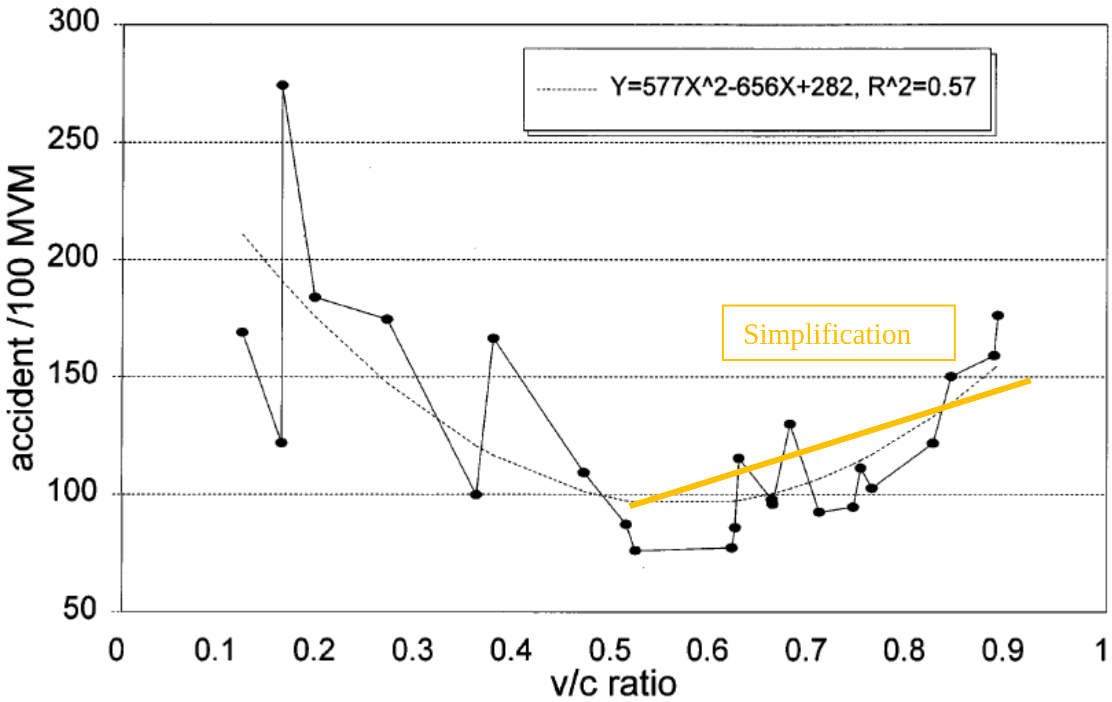

Figure 13: Correlation of number of accidents and capacity utilisation (Zhou and Sisiopiku 1997)

Travel time

The second component of the user costs is the lost travel time. The most important factor to calculate the lost travel time is the number of cars on the road at the moment. In a traffic counting they evaluated in total (includes both directions) 16’273 vehicles in one day on the Winterthurerstrasse (average daily traffic, ADT). The maximal cars per hour are on average 7 % of the ADT, which is assumed to be constant over 14 hours based on the graphics in the paper from the GIS-Browser. This leads to 1’139 current cars per hour in the observed system. (Kanton Zürich 2018a)

These numbers refer to the cars but not to the users, so the average car occupancy is assumed to be 1.6 passengers per car (Bundesamt für Statistik 2017). The capacity for the road network system is assumed to be 2’500 cars per hour for two lanes (one lane in each direction), based on Keller and Karel (2002). In addition, the capacity for three and four lanes are just upscaled and therefore 3’750 respectively 5’000 cars per hour. To calculate the lost travel time due to capacity problems, the distance driven and the reduction in speed have to be known. The distance is supposed to be in a 2 kilometres radius. The speed on this system is 50 km/h. The reduction in speed on the other hand is calculated to be 5 km/h per 150 more cars (Atkins 2009). The key point here is to say that when the system is exactly at its capacity limit there is already some congestion in the system. To consider this information we assumed that a reduction in speed starts on a two-lane infrastructure at 1’600 cars per hour. For the other number of lanes, it is assumed that they rise with the same factor.

The biggest part of this lost travel time makes the railway crossing right in the centre of Uster. This railway crossing is closed up to 40 minutes per hour, what means that it is 66 % of all the time closed during rush hours (Züri Ost 2015). In thoughts of the fact that the SBB continuously extend their offer which results in more trains on the rails the railway crossings will be even more closed. Because 66 % is the upper limit at the moment and we do not know the development, the assumption of a steady 66 % was made over the whole 50 years. The average waiting time per user who needs to wait is calculated to 20 minutes. Furthermore, the user distribution on the roads when the road ring is implemented will definitely change because of the immense traffic jams caused from the railway crossing. We assumed that the distribution would be 25 % over the old road to 75 % over the new road ring, but to have a certain deviation we used a normal distribution function to generate this percentages (see Figure 14). In the case that also an underpass for the railway crossing will be built, the distribution is assumed to be 50 % each of the ways, because the lost travel time due to the railway crossing will no longer exists and therefore both ways are equal attractive for the users.

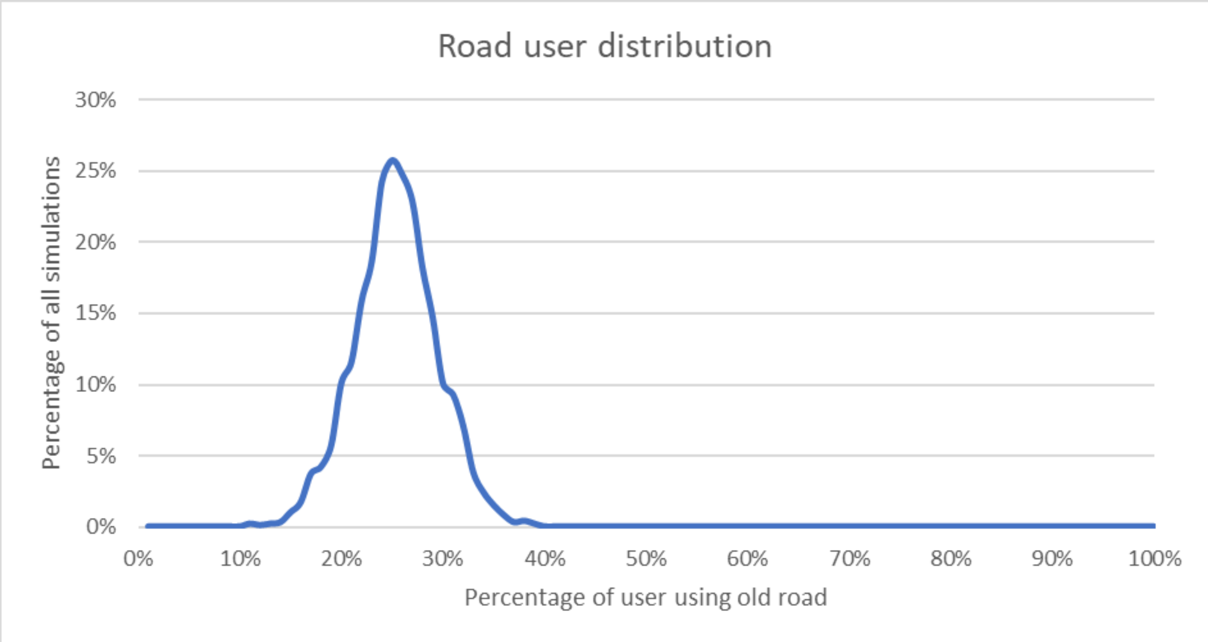

Figure 14: Normal distribution of user which uses old road after implementation of the road ring

Similarly, all these assumptions have to be made for the bike users. Unfortunately, in the traffic counting mentioned above no bikes where counted. For this reason, the assumption was made that 5 % of all habitants of Uster are using a bike (Biedermann et al. 2017). This gives a value of 1’750 bicycles in one day. Similar to the cars, the assumption of 7 % of the daily user as the maximum value over 14 hours gives 122.5 bikes per hour. A capacity limit of 3’500 bikes per hour was implemented and also a reduction in speed if 3’350 bikes per hour is exceeded (NACTO 2018). As you can observe in these numbers, the capacity of bikes will never be reached and therefore the costs due to capacity of bikes are always zero and have been excluded in our calculations. In contrast to the cars we assumed that only 50 % of all bike users are waiting at the railway crossing because some of them are taking a route which does not contain a railway crossing.

6.9.2 Cost calculations

In order to compare all the different scenarios and to evaluate which one is the best, the costs need to be calculated based on the formulas in chapter 6.5 and the assumptions made in the previous chapter 6.9.1.

For convenience the most important formulas for the cost calculations are shown here again. For more detailed explanation of the formulas consult chapter 6.5.

Main formula:

$$\mathrm{Min}[C_{Tot}] = \mathrm{Min}\left[C_{Owner} + C_{User,Car} + C_{User,Bik}\right] \tag{1}$$

Formula owner costs:

$$C_{Owner} = C_{Ini} + \sum_{t=0}^{T}(C_{Int,t} + \delta_t \cdot C_{Ext}) \tag{2}$$

Formula user costs for cars:

$$C_{User,Car} = \sum_{t=0}^{T}(C_{Saf,Car,t} + C_{TT,Car,t}) \tag{3}$$

Formula user costs for bikes:

$$C_{User,Bik} = \sum_{t=0}^{T}(C_{Saf,Bik,t} + C_{TT,Bik,t}) \tag{7}$$

As an example of the cost calculation, the first 7 years of the costs for the Normal Design are shown in Figure 15. On the top the distribution of old and new road is shown. Next to it, the number of car and bike users which have been simulated in chapter 6.4 are listed. The number of users is calculated in maximal user per hour (7 % of average daily traffic).

The owner costs include the construction and interventions. These values have been calculated based on the assumptions in chapter 6.8 and 6.9.1. The construction costs (C_{Ini}) only account in the year when the road ring is built and for the Flexible Design additionally the extension costs (C_{Ext}) when the network will get expanded. The intervention costs ($C_{Int,t}$) accrue for the road ring every year based on its width.

The user costs have been calculated separately for cars and bikes. The safety costs ($C_{Saf,t}$) result from the multiplication of the probability of an accident which depend on degree of utilisation of capacity with the costs for the accidents and the number of users in the network.

The lost travel time costs ($C_{TT,t}$) include two different elements. To determine the lost travel time due to the capacity, first needs to be calculated how fast the users can drive with the current number of users. From the difference in speed and the distance (2 km, chapter 6.9.1) the lost time can be established. This time needs to be multiplied by the number of users and the costs for the lost time per hour and user. This leads to the total costs which accrue due to the limited capacity. In Figure 15 are no costs for the lost travel time due to the capacity because the road is not used enough in the first 7 years that the users need to slow down. The costs for the lost travel time due to the railway crossing are calculated based on the assumption in chapter 6.9.1.2 that the crossing is closed 40 minutes per hour. Multiplying the involved 66 % of all daily car user with the average waiting time of 20 minutes and the costs for every lost hour gives the costs for the lost travel time due to the train crossing. As mentioned in the assumptions in chapter 6.9.1.2 only 50 % of the bikes are considered to pass the railway crossing and therefore only those bike user cause costs due to the lost travel time at the railway crossing.

Through adding up the owner and user costs for cars and bikes the total costs can be computed. As one of the last steps the discount ratio needs to be multiplied with the total costs in order to compare all scenarios on the same cost level. The discount ratio can be calculated with the following formula: $DR = \frac{1}{(1+r)^t}$ where r is the discount factor of 3 % and t the considered year.

Finally, the costs over all 50 years are added up to get the total discounted costs for one iteration. For every scenario 1’000 iterations have been done in order to get a stable result.

Iter.	percentage old road	Year	1	2	3	4	5	6	7
1	28%	# Car User per hour	1858	1893	1928	1956	1991	2054	2090
		# Bike User per hour	134	142	152	162	171	180	192
	Owner Costs	Construction	-	-	-	-	21’000’000	-	-
		Intervention	-	-	-	-	-	138’950	138’950
		Total Owner Costs	-	-	-	-	21’000’000	138’950	138’950
	User Costs Cars	Safety Cars	515’377	525’087	534’797	542’565	552’275	569’850	579’852
		Travel Time capacity	-	-	-	-	-	-	-
		Travel Time Train	116’022’936	118’208’881	120’394’825	122’143’581	124’329’525	35’761’190	36’388’827
		Total User Costs Cars	116’538’313	118’733’968	120’929’622	122’686’146	124’881’800	36’331’040	36’968’678
	User Costs Bike	Safety Bikes	109’220	116’064	123’478	132’033	139’447	146’862	156’272
		Travel Time Train	4’186’084	4’448’397	4’732’570	5’060’461	5’344’634	1’569’093	1’669’637
		Total User Costs Bikes	4’295’303	4’564’460	4’856’048	5’192’494	5’484’082	1’715’955	1’825’909
	Discountfactor		0.971	0.943	0.915	0.888	0.863	0.837	0.813
	Total	**2’940’219’545.31**	**120’833’616**	**123’298’428**	**125’785’670**	**127’878’640**	**151’365’882**	**38’185’945**	**38’933’538**
	Total incl. Discount	**1’612’831’357.45**	**117’314’190**	**116’220’594**	**115’111’706**	**113’618’515**	**130’569’539**	**31’980’128**	**31’656’529**

Figure 15: Example of cost calculations for the first 7 years of the Normal Design

Additionally, to the calculations above, for the Flexible Design the triggering condition needs to be implemented. The initial design is triggered when the cumulative cost difference is higher than the discounted expansion costs of 8 million CHF (compare chapter 6.8). In the year of triggering the additional extension costs (C_{Ext}) need to be paid and in all the following years the intervention costs double because the width is twice the size of the initial design. The safety and lost travel time depend on the capacity which also changes with the triggering of the road ring and therefore those costs will decrease.

The costs for scenarios with the underpass are similar with the difference that the traffic distributes equally over the old road and the new road ring (each 50 %) and no lost travel time costs due to a closed railway crossing will incur.

7 Results and discussion

7.1 Results

The simulations have been done for all the different designs, each one with and without the additional underpass. The simulations are done with the Monte Carlo Method, which was explained in chapter 3.1.1, whereas for every design 1000 simulation are carried out.

In Table 9 as a result of the simulations the median and standard deviation of the different designs are shown.

It can be seen when taking a look at the costs without an underpass, that the Normal Design has the lowest costs of 1’493’001’331 CHF. Following by the two Flexible Designs which are fairly close to each other with 1’497’493’216 CHF and 1’497’579’291 CHF, this is just a difference of 86’075 CHF. After those two, the Maximum Design with a cost of 1’501’518’584 CHF comes. By far the most expensive one is the Do Nothing strategy with 4’147’433’394 CHF. The standard deviation for the designs without an underpass shows that the Do Nothing strategy has the highest deviation with 581’860’062 CHF, which indicates a high instability. The lowest deviation has the Maximum Design, but all designs except for the Do Nothing one have nearly the same deviation, they vary from 206’062’092 CHF down to 198’579’407 CHF.

In the case with an underpass the situation is a bit different. Indeed, the design with the lowest costs is the same as without an underpass, namely the Normal Design with 70’098’527 CHF and also followed by the two Flexible Designs with both 77’862’006 CHF. The big difference is now that the design with the highest costs is no more the Do Nothing but instead the Maximum Design with 85’521’472 CHF. The Do Nothing strategy has costs of 80’478’496 CHF. The Maximum Design has in this case the lowest deviation with 3’119’647 CHF, followed by the Normal Design with 4’036’297 CHF. The two Flexible Design have nearly the same deviation with 3’643’222 CHF and 3’649’579 CHF. With distance the biggest deviation shows the Do Nothing strategy with 90’520’077 CHF.

Table 9: Mean and standard deviation of the costs of each design

		Median [CHF]	Standard Deviation [CHF]
Without Underpass	Do Nothing	4’147’433’394	581’860’062
	Normal Design	1’493’001’331	206’062’092
	Maximum Design	1’501’518’584	198’579’407
	Flexible Design 4 lanes	1’497’579’291	201’854’587
	Flexible Design 3 lanes	1’497’493’216	201’981’056
With Underpass	Do Nothing	80’478’496	90’520’077
	Normal Design	70’098’527	4’036’297
	Maximum Design	85’521’472	3’119’647
	Flexible Design 4 lanes	77’862’006	3’649’579
	Flexible Design 3 lanes	77’862’006	3’643’222

Figure 16 shows the resulting graphic for the cumulative probability of the costs of all the different design variants. The slope of the curves indicates the standard deviation, this means a flat curve indicates a big standard deviation and a steep curve indicates a smaller standard deviation.

At first, we see that by far the most expensive design is where you do nothing. Furthermore, it can be seen, that all the designs in combination with the underpass are cheaper than the ones without an underpass. Because of the fact that the costs are very widespread, the different designs without underpass overlap mostly, as well as the ones with an underpass. For this reason, they are shown separately in the following diagrams.

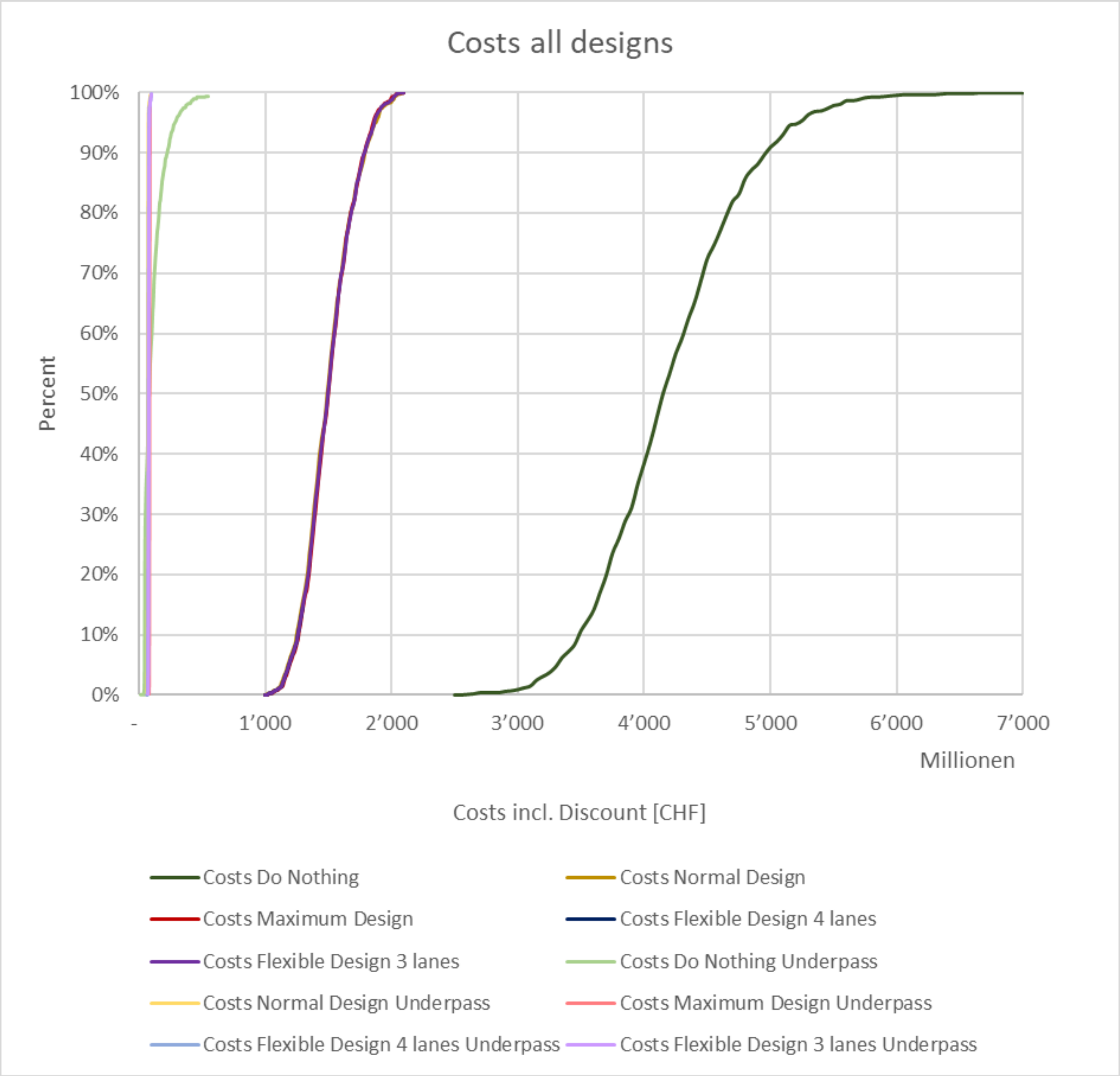

Figure 16: Cumulative probability of the costs for each design

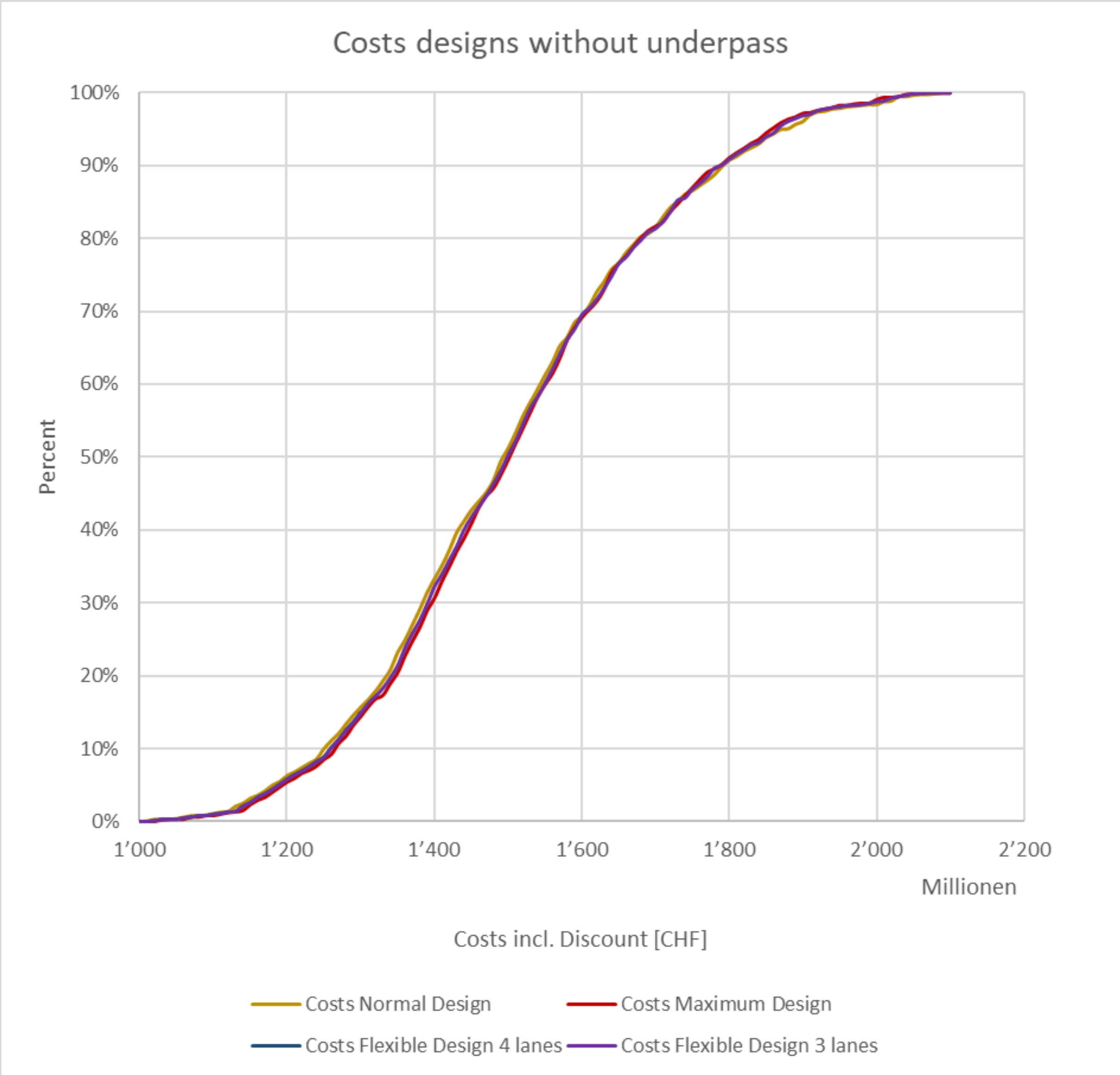

Figure 17: Cumulative probability of the costs for each design without an underpass

In Figure 17 only the designs without the underpass are shown. After taking a closer look at the designs without an underpass in Figure 18 (it is the same graph as Figure 17 but just zoomed in in the range of 45 % to 55 %), one can observe that the Normal Design has the lowest costs, but all designs are fairly close to each other. The dotted lines show the values for the different designs where 50 % of all costs are higher or lower (median).

It can be seen, that the Normal Design has the lowest costs, followed by the two Flexible Designs which are fairly close to each other. The Maximum Design is in Figure 18 the most expensive.

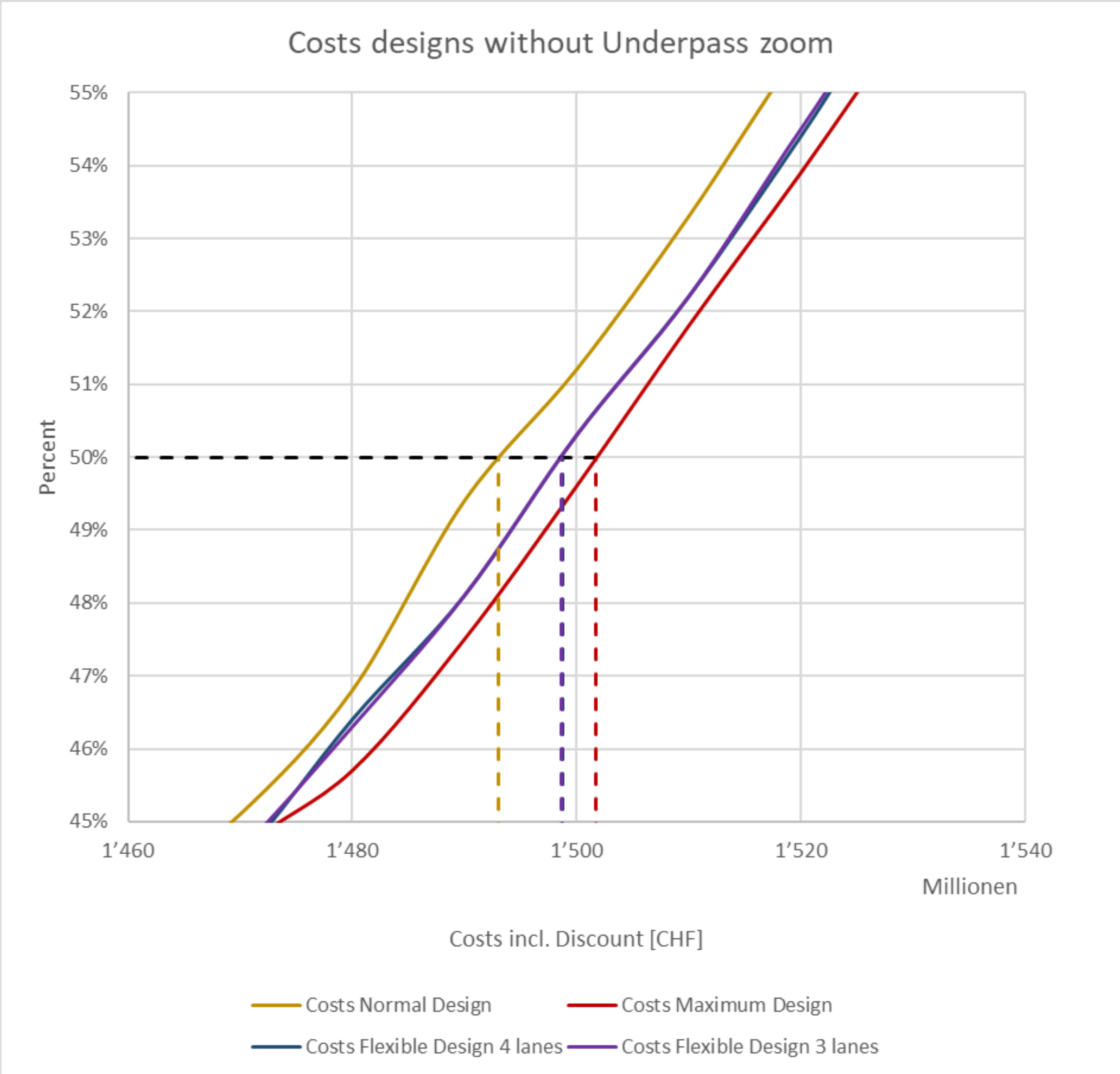

Figure 18: Cumulative probability of the costs for each design without an underpass, zoomed in

In Figure 19 the costs of the different designs with the underpass are shown. In this case the results are a bit different. Now the design with the highest costs is no more the Do Nothing Design but instead the Maximum Design. The rest is almost the same with just much lower costs than without the underpass. The cheapest is still the Normal Design, followed by the two Flexible Designs, which are so similar that the curves are mostly overlapping.

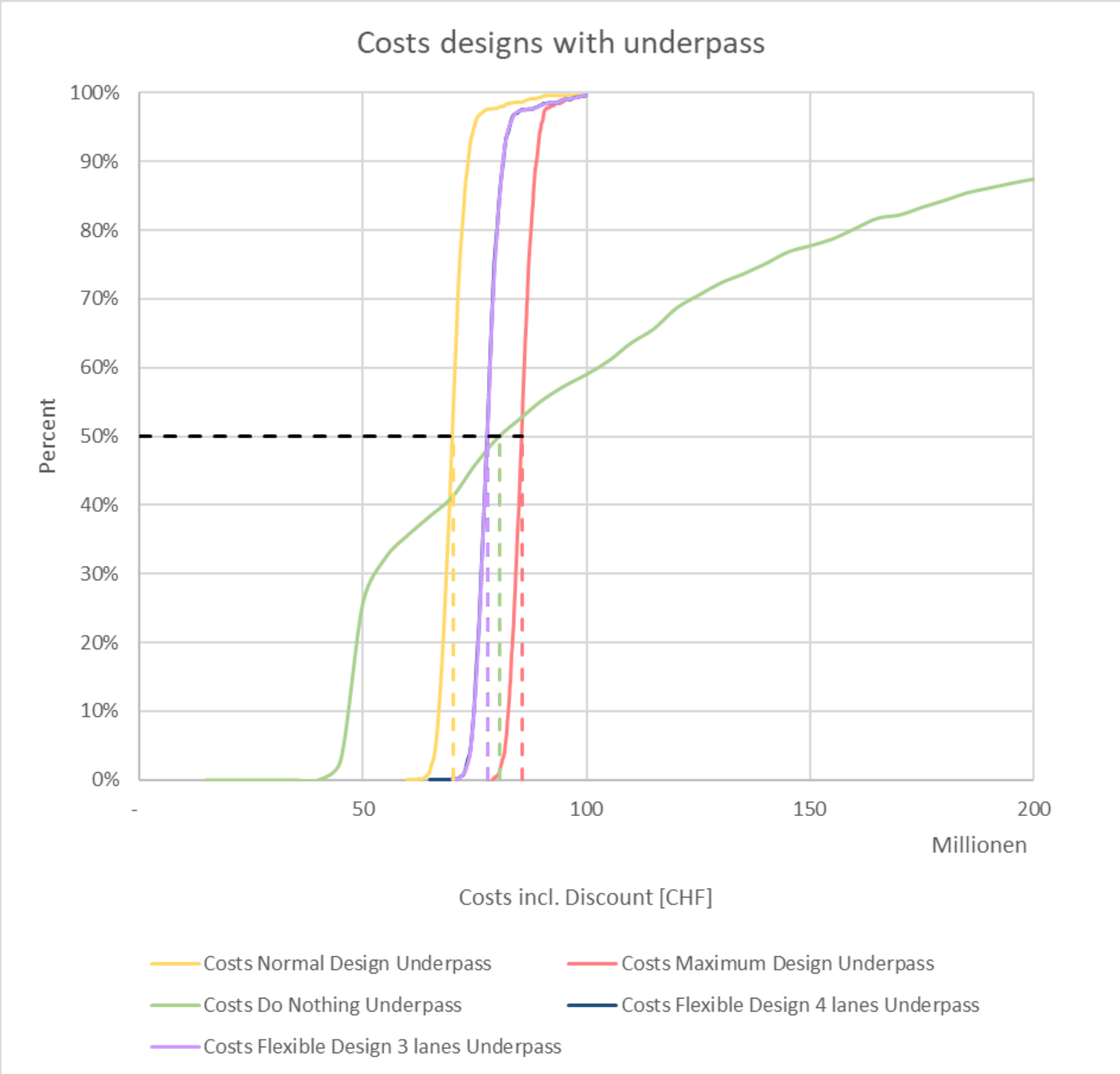

Figure 19: Cumulative probability of the costs for each design with an underpass

7.2 Discussion

In this chapter the results from chapter 7.1 are discussed and compared with each other in order to evaluate which design scenario is the best for the existing road network of User.

7.2.1 Discussion without underpass

In Figure 16 can be observed the difference between all the scenarios with and without the road ring and the Do Nothing strategy. It is obvious that doing nothing is the worst case. This is because the costs for the lost travel time at the railway crossing are immense. Only the fact that the crossing is closed for 40 minutes per hour and the corresponding costs legitimate the implementation of the road ring. The higher standard deviation of the Do Nothing strategy can be explained with the fact that the capacity is lower and therefore not only the costs for the railway crossing are high but also as soon as the traffic reaches a certain level the user costs due to capacity increase additionally because of the reduced speed and the corresponding lost travel time. Therefore, for simulations with a high number of future traffic users, the costs become very high. The costs for the construction of the road ring and the intervention costs are almost neglectable small compared to the costs which incur through the waiting time at the railway crossing in the Do Nothing scenario. All this leads to the fact that if no underpass exists it is obvious that the construction of the road ring is worth the investment.

Having observed that the implementation of the road ring makes sense, it needs to be discussed how the road ring is implemented best. When considering Figure 17 it can be observed that all the scenarios are really close to each other and therefore it needs to be zoomed in (see Figure 18) to discuss the differences. Out of Table 9 can be calculated that the difference of the total discounted costs of the median between the Normal and Maximum Design is 8.5 million swiss francs. On the other hand, the additional discounted initial construction costs are about 12.5 million swiss francs. This shows that the additional costs for the higher capacity of the network are not justifiable because the decrease in user costs is quite small since the capacity of the Normal Design is already high enough that only in very few simulations congestion will occur on the road and therefore are the lost travel time costs due to capacity mostly zero. This leads to the fact that the savings of the Maximum Design mainly come from the safety costs which according to Figure 13 decrease if the capacity utilisation is lower. This reduction in user costs however is not enough to justify the higher initial construction costs of the Maximum Design of the road ring.

In a last step the Normal and Flexible Designs need to be compared. In Figure 18 can be seen that the two different extension possibilities of the Flexible Design make almost no difference in costs. Both of the designs, either four mixed or three mixed and one bike lane have enough capacity to meet the demand in the upcoming 50 years. The reduction of safety costs on one hand due to lower capacity utilization in the four lanes design and on the other hand due to the separate bike lane in the other design almost counterbalance each other and therefore the total costs are very similar. Comparing the Flexible with the Maximum Design shows that it is better to build it flexible even if the total construction costs are higher. This can be explained by taking the discount factor into account and having in mind that the Maximum Design is more beneficial in the future when the number of users is higher leads to the result that it would be better to build a smaller flexible road ring in the beginning and then expand when the construction costs are discounted more and the benefits of a higher capacity have a higher impact. In our simulation, in 15 % of the iterations the triggering condition was reached and it was worth to expand the initial design. However if the Normal and the Flexible Designs are compared it can be recognised that the median of the total discounted costs of the Normal Design is approximately 4.5 milion swiss francs cheaper. The reason for this is similar to the explanation why the Maximum Design is not worth the invested money. The capacity of the Normal Design is in most of the simulations sufficient and the additional investment for the flexibility is not worth it considering the next 50 years.

In conculusion, the best initial design with our simulations and assumptions, for the case without an underpass in the city centre, is the Normal Design.

7.2.2 Discussion with underpass

It does not matter which scenario is considered, the total costs are always lower if an underpass has been implemented initially (see Figure 16). This huge difference in costs comes with the fact that with the implementation of an underpass no cars and bikes need to wait anymore at the crossing and therefore the costs due to lost travel time drop drastically. In Figure 19 all designs with an underpass are displayed. The Do Nothing scenario has a standard deviation which is a lot higher than all the other designs. This comes from the fact that the capacity often cannot meet the demand of the traffic and therefore in the simulations with a high number of future users the costs rise heavily. The other three scenarios behave really similar to the same scenarios in the case without an underpass. The cost difference between the Normal and Maximum Design is even larger with more than 15 million swiss francs. This comes from the fact that the distribution of the traffic between old and new road is assumed to be equal in the case with an underpass and therefore less vehicles use the road ring compared to the scenarios without an underpass and consequently it is even less worth to build the Maximum Design if an underpass exists. Exactly the same considerations lead to the conclusion that also the Flexible Designs do not make sense to implement. To sum up, the Normal Design is also the best decision if an underpass exists.

8 Sensitivity analysis

In this chapter it will be observed what effect a change in the assumed input parameters has on the modelled results. Therefore, the aspects which influence the costs of a design the most will be slightly changed in their values and afterwards an evaluation of the changed results will be done with a sensitivity analysis. Because the user distribution on the roads (old road and new road ring, with and without an underpass) has a fairly high influence on the total costs and is difficult to predict without using a traffic simulation, a sensitivity analysis concerning the user distribution on the two roads is done.

8.1 User distribution on the two roads

In chapter 7 all the results can be seen which are based on the assumptions for the user costs in chapter 6.9.1.2. The user distribution on the old road and the new road ring are assumed to be 25 % and 75 % without the underpass and 50 % each with the underpass. Behind these assumptions are approximate expectations and therefore a sensitivity analysis on these values makes sense.

8.1.1 Without underpass

The sensitivity analysis is done for a lower user distribution on the old road (20 %) and 80 % on the road ring, and a higher one with 30 % on the old path, which are still plausible happenings. After doing the 1000 simulations with the adjusted user distribution, one can see the impact on the costs of the designs in Table 10.

It can be observed, that the values for different user distributions on the roads change the resulting total costs heavily. For the distribution with the 20 % on the old road, the costs are between roughly 1’328 Mio. CHF and 1’335 Mio. CHF. These values are significantly lower than the costs for the initial distribution of 25 %. On the other hand, the costs for the higher distribution with 30 % are quite higher with 1’665 Mio CHF to 1’677 Mio. CHF. Summing it up, for all the designs with the distribution of 20 % the costs are around 166 Mio. CHF less than for the assumed distribution of 25 % and 175 Mio. CHF more for the 30 % distribution. This is because when more people are using the old road, on which huge lost travel time costs due to the closed railway crossing occur, the overall costs rise. Respectively the costs decrease when less people use the old road, as one can see in Figure 20. The quintessence is that this distribution on the roads and the whole system should be modelled to get a concrete value for the costs. Nevertheless in Figure 21 can be seen, that the order of the designs in the median does not change throughout the different user distribution on the two roads. The Normal Design has always the lowest costs, the Maximum Design the highest and in between are the two Flexible Designs.

Table 10: Median and standard deviation with different user distributions on the two roads without the underpass

		Median [CHF]	Standard Deviation [CHF]	Median difference to 25 % [CHF]
Without Underpass	Normal Design 20 %	1’328’556’479	188’729’646	-164’444’852
	Normal Design 25 %	1’493’001’331	206’062’092	
	Normal Design 30 %	1’665’333’525	218’808’505	172’332’194
	Maximum Design 20 %	1’334’903’377	178’409’302	-166’615’207
	Maximum Design 25 %	1’501’518’584	198’579’407	
	Maximum Design 30 %	1’677’004’978	213’675’633	175’486’394
	Flexible Design 4 lanes 20 %	1’331’190’128	181’716’056	-166’389’162
	Flexible Design 4 lanes 25 %	1’497’579’291	201’854’587	
	Flexible Design 4 lanes 30 %	1’673’097’004	216’593’962	175’517’713
	Flexible Design 3 lanes 20 %	1’330’852’512	181’986’286	-166’640’704
	Flexible Design 3 lanes 25 %	1’497’493’216	201’981’056	
	Flexible Design 3 lanes 30 %	1’673’097’004	216’638’759	175’603’788

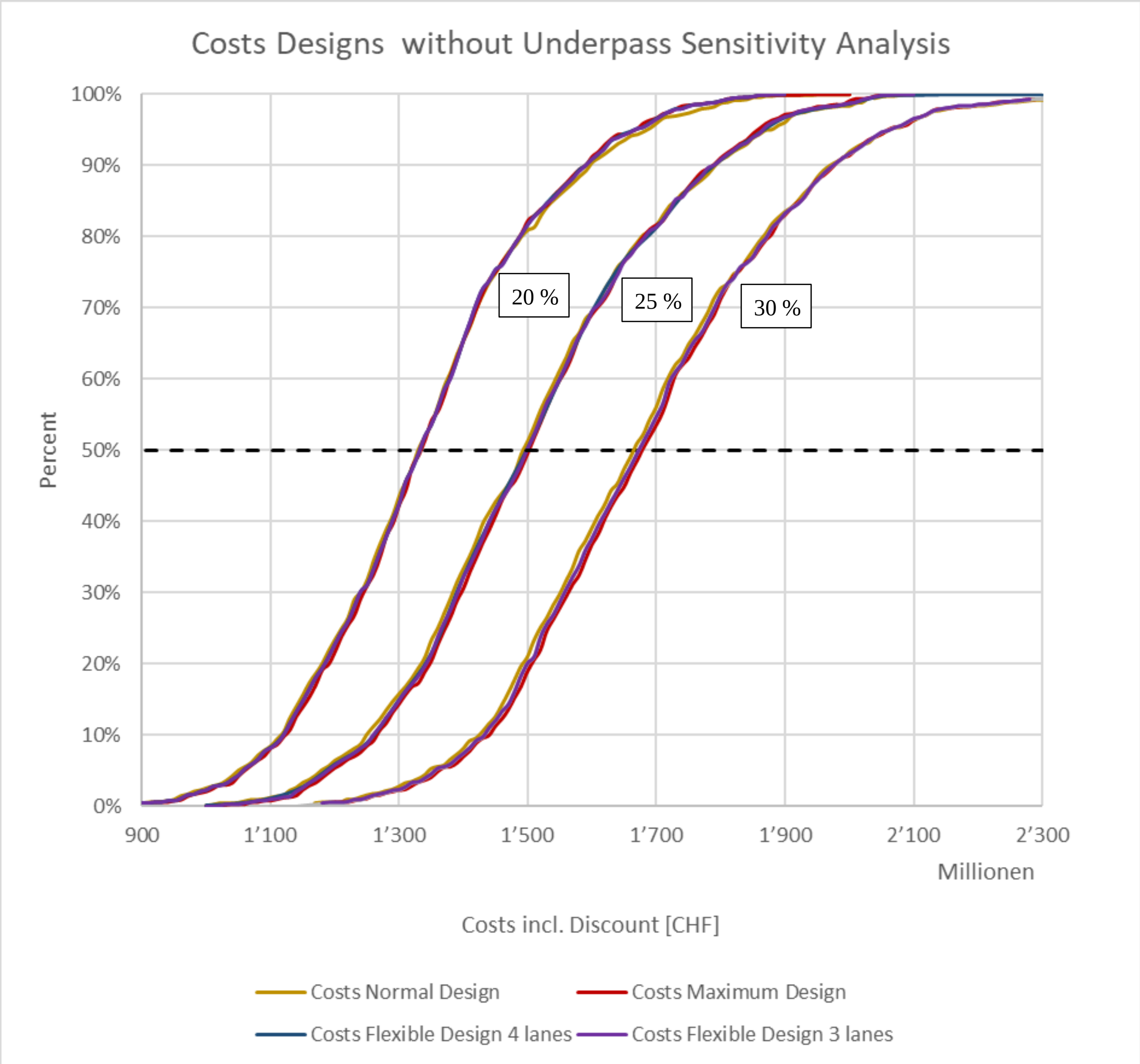

Figure 20: Cumulative probability of the costs for each design and each distribution without an underpass

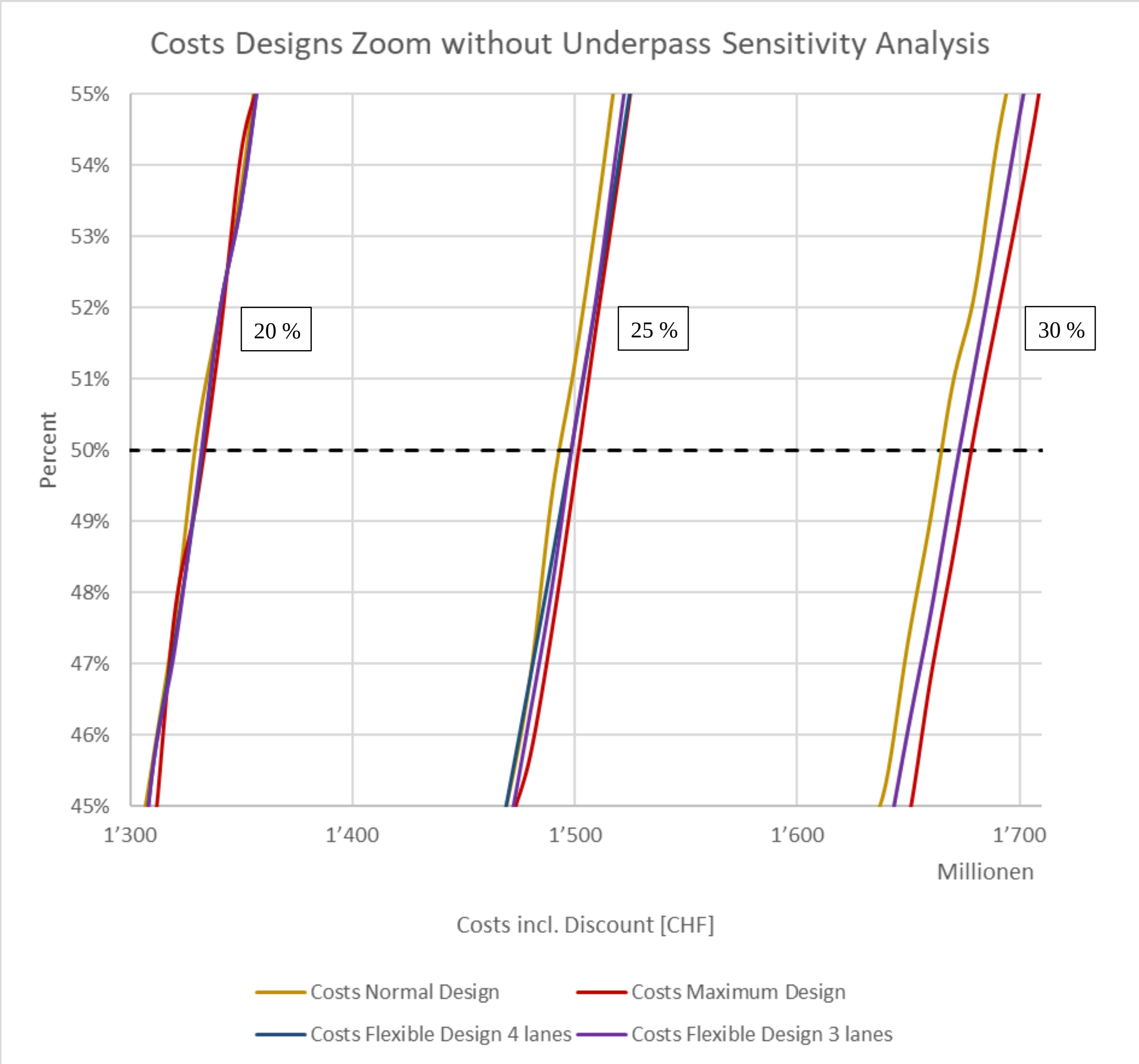

Figure 21: Cumulative probability of the costs for each design and each distribution without an underpass, zoomed

8.1.2 With underpass

With the adjusted user distribution for the case with the underpass the impact on the costs of the designs can be seen in Table 11.

As it can be seen in Table 11, the values for different user distributions on the roads change the resulting costs just a little. For the distribution with the 45 % and 55 % on the old road, the costs are both between roughly 70 Mio. CHF and 85 Mio. CHF. The costs are just around 2’200 CHF more than for the initially assumed distribution of 50 %. This is because either when there are more people on one road or the other, the costs rise in terms of capacity. With a distribution of 50 % the capacity of all roads is used the best way because the old road and the new road ring with two lanes have exactly the same capacity and there are no costs due to the waiting at the railway crossing. Taking a look at the Maximum Design, it can be observed that the cost difference is slightly higher when 55 % use the old road, the reason is because in this design the road ring has the higher capacity and therefore it is worse when more people use the old road which is smaller. The fact that there are no big differences in the values of the total costs, also the order of the designs does not change. The Normal Design has again the lowest costs, the Maximum Design the highest and in between are the two Flexible Designs.

Table 11: Median and standard deviation with different user distributions on the two roads with the underpass

		Median [CHF]	Standard Deviation [CHF]	Median difference to 50 % [CHF]
With Underpass	Normal Design 45 %	70’100’725	4’357’579	2’199
	Normal Design 50 %	70’098’527	4’036’297	
	Normal Design 55 %	70’100’725	4’203’384	2’199
	Maximum Design 45 %	85’521’472	2’531’271	-
	Maximum Design 50 %	85’521’472	3’119’647	
	Maximum Design 55 %	85’547’353	3’911’718	25’882
	Flexible Design 4 lanes 45 %	77’864’205	4’031’705	2’199
	Flexible Design 4 lanes 50 %	77’862’006	3’649’579	
	Flexible Design 4 lanes 55 %	77’864’205	4’203’384	2’199
	Flexible Design 3 lanes 45 %	77’864’205	4’022’767	2’199
	Flexible Design 3 lanes 50 %	77’862’006	3’643’222	
	Flexible Design 3 lanes 55 %	77’864’205	4’203’384	2’199

9 Conclusion, Limitations and Outlook

9.1 Conclusion

In conclusion, based on the results and discussion in chapter 7 and the sensitivity analysis in chapter 8 the Normal Design is in all scenarios the best initial design. With our considerations and assumptions, the additional initial costs to build the infrastructure in a flexible way is not worth the money. The best scenario to solve the traffic problems in Uster with minimal costs is to build an underpass in the city centre and the road ring Uster west.

However, in our work, we did not consider political issues and the available budget of the canton Zürich and the city of Uster. This could lead to the decision that only one of the two possible infrastructure expansions can be built. In this case, it is recommended to build only the underpass. The total costs over 50 years are lower for the Do Nothing strategy with underpass than for the Normal Design without underpass.

It needs to be mentioned, that with other assumptions and the consideration of different stakeholders and key parameters it might be possible that the results change. Due to the limited scope of our project work, not everything could be considered. In our opinion it would be interesting to include also the directly affected public (DAP) into the calculations because the road through the city produces a lot of noise and smell which also could be considered as costs. Additionally, the impact of the road ring on the ecosystem of the surrounding area has not been taken into account. The fact that the road ring passes a nature protection area makes the implementation more difficult and could also be considered with additional costs.

9.2 Limitations

For our project work we used the Real Option Methodology which mainly is made for the evaluation of single infrastructure. Throughout our work we adapted some elements slightly in order to make it more suitable for our approach. In general, if you have only one building, the selection of the considered stakeholders is not so difficult and crucial because it does not have a huge impact on many people and therefore often only the owner costs are considered. In order to use the Real Option Methodology for entire networks it is advisable to create a new step in the beginning for the definition of the stakeholders or add this issue to the first step, like we did it.

A further difference is that if you evaluate an infrastructure network, in the future many buildings in this area will be build which have an influence on the network like a new hospital or a train station in our case study. For such changes two Monte Carlo Simulations are needed because one is used for the probability of implementation and the other to simulate the consequence of the implemented infrastructure. This needs to be considered in the part about the simulation of the uncertainty because in normal Real Option studies only one simulation for each key parameter is used. These additional simulations and the high number of key parameters also lead to the fact that many simulations need to be done. For our project work we used Microsoft Excel and recognised that this program is not construed for such an amount of iterations. This led to the fact that the files were too big and we needed to split it up in several files. For further studies we thus recommend using another program with higher calculation capacity to run the simulations.

Additionally, a difference between analysing a single object or a network is that often different expansion possibilities exists, and this leads to a lot of different possible scenarios. We only considered an implementation of the road ring and the underpass but for sure there would be other solutions for the city of Uster. Adding even more scenarios would make it very confusing in our opinion and there we see a limitation of the Real Option Methodology for entire networks.

9.3 Outlook

The scope of the topic we worked on in this project work is quite large. We reduced the scope in order to get good results in the given time period. But there are many things which could be considered additionally or more detailed. As already mention in chapter 9.1 the directly affected public (DAP) could also be taken into consideration. Additionally, political decisions and budget limits of the city and the canton could be implemented in the case study. A last suggestion for further studies is the modelling of the traffic in the city. We assumed an equally distributed traffic in the city in the initial state and only estimated a different distribution on the old road and the new road ring, but in reality, obviously all cars use different ways which lead to other traffic models. With such a traffic simulation the results could be calculated more precisely than we did it with our simple assumptions of the traffic distribution.

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11 Appendices

11.1 Probability distribution of key parameters

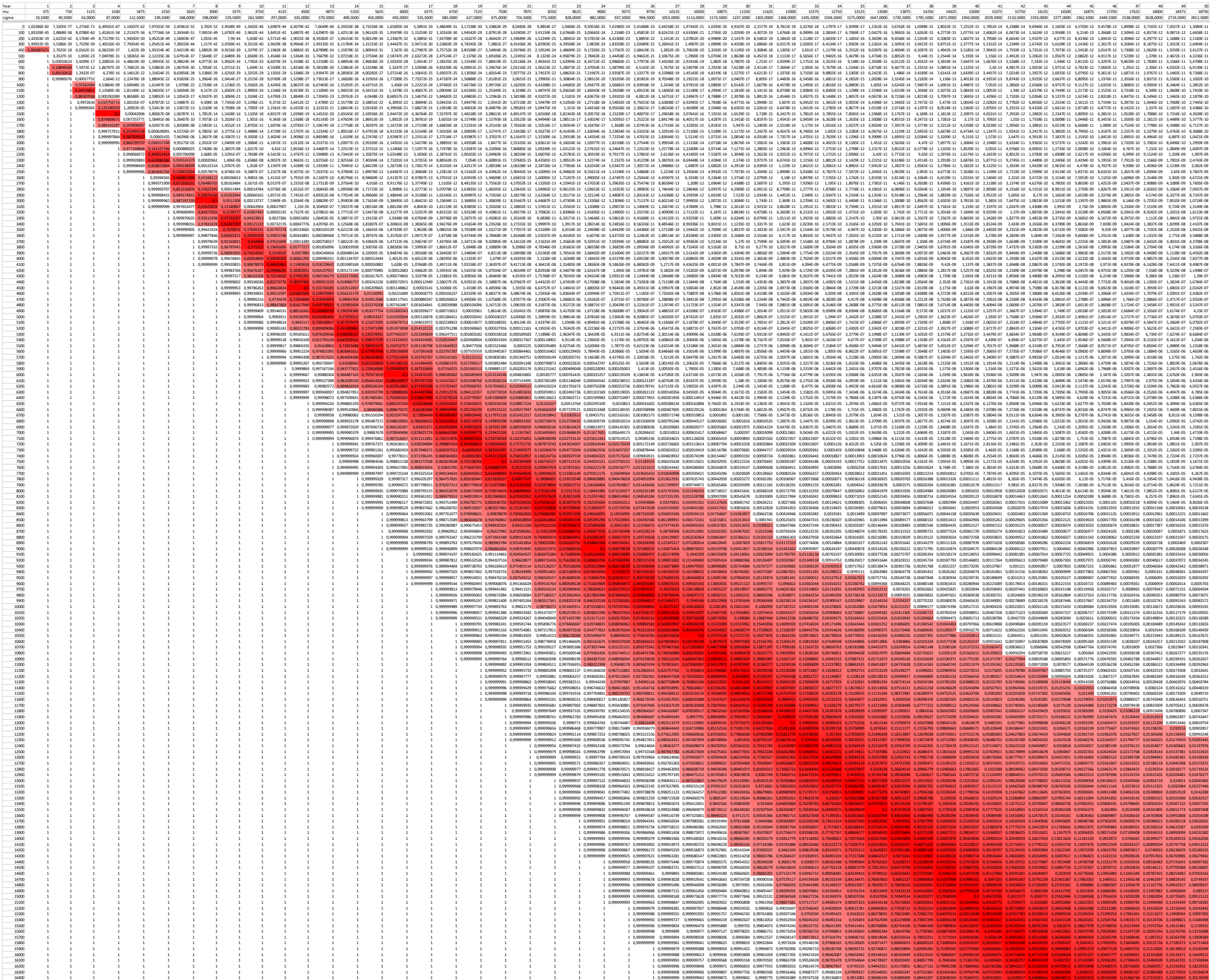

Figure 22: Distribution of additional daily car users due to growth in population

Year	1	2	3	4	5	6	7	8	9	10
mu	375	750	1125	1500	1875	2250	2625	3000	3375	3750
sigma	19,5000	40,5000	63,0000	87,0000	112,5000	139,5000	168,0000	198,0000	229,5000	262,5000
0	1,02286E-82	7,3205E-77	1,2716E-71	6,49501E-67	1,14507E-62	7,97501E-59	2,45961E-55	3,702E-52	2,9548E-49	1,3432E-46
100	1,83109E-45	2,8868E-58	8,0788E-60	1,45261E-58	2,21247E-56	6,77736E-54	2,34344E-51	7,0955E-49	1,6792E-46	2,9632E-44
200	1,42503E-19	2,6225E-42	4,1704E-49	8,71179E-51	1,94592E-50	3,45253E-49	1,56903E-47	1,055E-45	7,9E-44	5,658E-42
300	5,99932E-05	5,5386E-29	1,7529E-39	1,40216E-43	7,79354E-45	1,05451E-44	7,38333E-44	1,217E-42	3,0769E-41	9,3515E-40
400	0,900087671	2,7625E-18	6,0162E-31	6,06233E-37	1,422E-39	1,93154E-40	2,44219E-40	1,0892E-39	9,9216E-39	1,3379E-37
500	1	3,3537E-10	1,693E-23	7,04978E-31	1,18265E-34	2,12235E-36	5,67914E-37	7,5648E-37	2,6489E-36	1,6569E-35
600	1	0,00010624	3,9299E-17	2,20855E-25	4,48619E-30	1,39935E-32	9,28624E-34	4,0772E-34	5,8562E-34	1,7765E-33
700	1	0,10849568	7,5972E-12	1,86797E-20	7,76812E-26	5,53863E-29	1,06793E-30	1,7056E-31	1,0721E-31	1,649E-31
800	1	0,89150432	1,2432E-07	4,278E-16	6,14613E-22	1,31654E-25	8,63956E-28	5,5386E-29	1,6256E-29	1,3252E-29
900	1	0,99989376	0,00017752	2,664E-12	2,22478E-18	1,88045E-22	4,91826E-25	1,3964E-26	2,0414E-27	9,2215E-28
1000	1	1	0,02362084	4,53864E-09	3,69048E-15	1,61497E-19	1,9708E-22	2,7338E-24	2,1236E-25	5,5565E-26
1100	1	1	0,34574811	2,13589E-06	2,81149E-12	8,34635E-17	5,56094E-20	4,157E-22	1,8302E-23	2,8995E-24
1200	1	1	0,88307036	0,000282089	9,86588E-10	2,59832E-14	1,10542E-17	4,9107E-20	1,3069E-21	1,3104E-22
1300	1	1	0,9972634	0,010756713	1,60135E-07	4,87872E-12	1,54887E-15	4,508E-18	7,7343E-20	5,1296E-21
1400	1	1	0,99999365	0,125190329	1,20953E-05	5,53413E-10	1,53072E-13	3,2169E-16	3,7938E-18	1,7395E-19
1500	1	1	1	0,5	0,00042906	3,80067E-08	1,06787E-11	1,7852E-14	1,5428E-16	5,1105E-18
1600	1	1	1	0,874809671	0,007253771	1,58491E-06	5,26407E-10	7,7073E-13	5,2026E-15	1,301E-16
1700	1	1	1	0,989243287	0,059906907	4,02927E-05	1,83589E-08	2,5902E-11	1,4552E-13	2,8702E-15
1800	1	1	1	0,999717911	0,252492538	0,000628091	4,53726E-07	6,7805E-10	3,3775E-12	5,4888E-14
1900	1	1	1	0,999997864	0,587929552	0,00605435	7,96296E-06	1,3837E-08	6,5067E-11	9,1003E-13
2000	1	1	1	0,999999995	0,866739737	0,036557298	9,95175E-05	2,2032E-07	1,0409E-09	1,3084E-11
2100	1	1	1	1	0,977249868	0,141127196	0,000889025	2,7408E-06	1,3837E-08	1,6317E-10
2200	1	1	1	1	0,998066972	0,360013414	0,005706998	2,668E-05	1,5291E-07	1,7658E-09
2300	1	1	1	1	0,999920883	0,639986586	0,026524379	0,00020361	1,406E-06	1,6586E-08
2400	1	1	1	1	0,999998469	0,858872804	0,090238839	0,00122154	1,0767E-05	1,353E-07
2500	1	1	1	1	0,999999986	0,963442702	0,228423834	0,00578076	6,8746E-05	9,5887E-07
2600	1	1	1	1	1	0,99394565	0,440851968	0,02168122	0,00036653	5,9081E-06
2700	1	1	1	1	1	0,999371909	0,672356151	0,06486702	0,00163484	3,1671E-05
2800	1	1	1	1	1	0,999959707	0,851216876	0,15622345	0,00611484	0,00014784
2900	1	1	1	1	1	0,999998415	0,949174815	0,30676168	0,01923944	0,00060165
3000	1	1	1	1	1	0,999999962	0,987197239	0,5	0,0511308	0,00213737
3100	1	1	1	1	1	0,999999999	0,997653477	0,69323832	0,11540847	0,00663964
3200	1	1	1	1	1	1	0,999689895	0,84377655	0,2228727	0,01807492
3300	1	1	1	1	1	1	0,999970635	0,93513298	0,37191057	0,04323813
3400	1	1	1	1	1	1	0,999998016	0,97831878	0,54337197	0,09121122
3500	1	1	1	1	1	1	0,999999905	0,99421924	0,7070071	0,17045191
3600	1	1	1	1	1	1	0,999999997	0,99877846	0,83655371	0,28385458
3700	1	1	1	1	1	1	1	0,99979639	0,92163011	0,424468
3800	1	1	1	1	1	1	1	0,99997332	0,96797645	0,575532
3900	1	1	1	1	1	1	1	0,99999726	0,98891905	0,71614542
4000	1	1	1	1	1	1	1	0,99999978	0,99676845	0,82954809
4100	1	1	1	1	1	1	1	0,99999999	0,99920855	0,90878878
4200	1	1	1	1	1	1	1	1	0,99983766	0,95676187
4300	1	1	1	1	1	1	1	1	0,99997217	0,98192508
4400	1	1	1	1	1	1	1	1	0,99999602	0,99336036
4500	1	1	1	1	1	1	1	1	0,99999953	0,99786263

Figure 23: First 10 years of distribution of additional daily car users due to growth in population

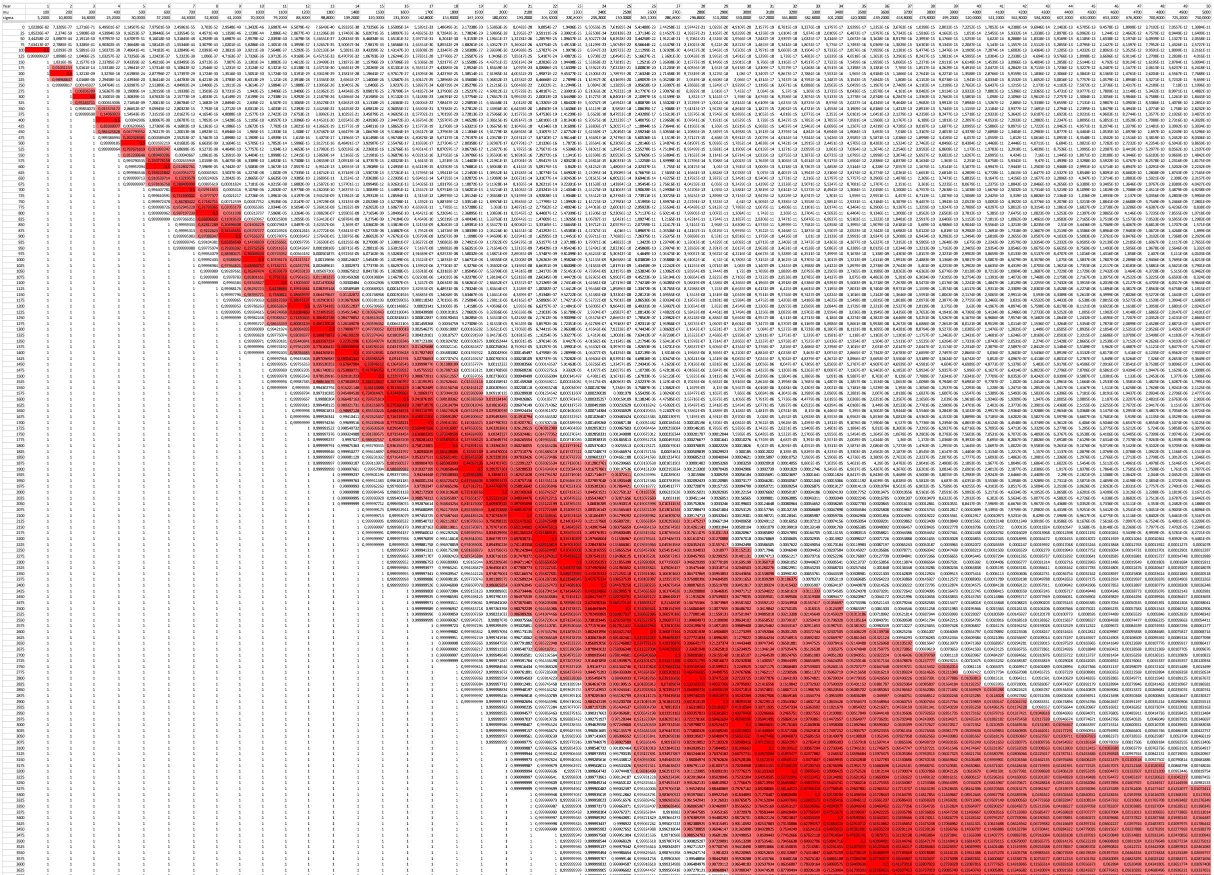

Figure 24: Distribution of additional daily bike users due to growth in population

Year	1	2	3	4	5	6	7	8	9	10
mu	100	200	300	400	500	600	700	800	900	1000
sigma	5,2000	10,8000	16,8000	23,2000	30,0000	37,2000	44,8000	52,8000	61,2000	70,0000
0	1,02286E-82	7,3205E-77	1,2716E-71	6,49501E-67	1,14507E-62	7,97501E-59	2,45961E-55	3,702E-52	2,9548E-49	1,3432E-46
25	1,85226E-47	2,374E-59	1,5908E-60	4,53994E-59	9,16253E-57	3,38446E-54	1,33554E-51	4,4571E-49	1,1359E-46	2,1238E-44
50	3,44258E-22	3,6987E-44	2,1911E-50	9,97957E-52	3,67097E-51	9,16018E-50	5,31845E-48	4,2929E-46	3,6987E-44	2,9579E-42
75	7,63413E-07	2,7885E-31	3,3285E-41	6,90302E-45	7,36648E-46	1,58142E-45	1,55346E-44	3,3079E-43	1,0201E-41	3,6286E-40
100	0,5	1,0293E-20	5,5891E-33	1,50372E-38	7,40641E-41	1,74182E-41	3,32849E-41	2,0393E-40	2,3831E-39	3,9211E-38
125	0,999999237	1,8998E-12	1,0406E-25	1,03257E-32	3,73256E-36	1,22423E-37	5,2322E-38	1,006E-37	4,7163E-37	3,7326E-36
150	1	1,8316E-06	2,1577E-19	2,23785E-27	9,43359E-32	5,49216E-34	6,03495E-35	3,9712E-35	7,907E-35	3,1301E-34
175	1	0,01031153	5,0161E-14	1,53318E-22	1,19641E-27	1,57314E-30	5,10842E-32	1,2546E-32	1,1231E-32	2,3124E-32
200	1	0,5	1,3213E-09	3,3276E-18	7,61985E-24	2,87796E-27	3,17397E-29	3,1724E-30	1,3516E-30	1,5051E-30
225	1	0,98968847	4,0168E-06	2,29458E-14	2,43936E-20	3,36414E-24	1,44783E-26	6,4213E-28	1,3783E-28	8,6313E-29
250	1	0,99999817	0,00145927	5,04764E-11	3,92987E-17	2,51389E-21	4,84992E-24	1,0406E-25	1,1911E-26	4,3614E-27
275	1	1	0,06836289	3,56367E-08	3,19089E-14	1,20159E-18	1,19338E-21	1,3503E-23	8,7231E-25	1,942E-25
300	1	1	0,5	8,15001E-06	1,30839E-11	3,67632E-16	2,15773E-19	1,4033E-21	5,4149E-23	7,6199E-24
325	1	1	0,93163711	0,000613006	2,71654E-09	7,20613E-14	2,86784E-17	1,1682E-19	2,8494E-21	2,635E-22
350	1	1	0,99854073	0,015574172	2,86652E-07	9,05945E-12	2,80323E-15	7,792E-18	1,2712E-19	8,0313E-21
375	1	1	0,99999598	0,14060923	1,54543E-05	7,31515E-10	2,01627E-13	4,1654E-16	4,8088E-18	2,1577E-19
400	1	1	1	0,5	0,00042906	3,80067E-08	1,06787E-11	1,7852E-14	1,5428E-16	5,1105E-18
425	1	1	1	0,85939077	0,006209665	1,27369E-06	4,16803E-10	6,1361E-13	4,1986E-15	1,0672E-16
450	1	1	1	0,984425828	0,047790352	2,76217E-05	1,20013E-08	1,6923E-11	9,6946E-14	1,965E-15
475	1	1	1	0,999386994	0,202328381	0,000389409	2,55253E-07	3,7467E-10	1,8998E-12	3,1909E-14
500	1	1	1	0,99999185	0,5	0,003592219	4,01682E-06	6,6635E-09	3,1604E-11	4,5705E-13
525	1	1	1	0,999999964	0,797671619	0,021893242	4,68698E-05	9,5272E-08	4,4649E-10	5,7757E-12
550	1	1	1	1	0,952209648	0,089460286	0,00040667	1,0961E-06	5,3591E-09	6,4404E-11
575	1	1	1	1	0,993790335	0,250778158	0,002633949	1,0159E-05	5,4675E-08	6,3389E-10
600	1	1	1	1	0,99957094	0,5	0,012802761	7,5969E-05	4,7442E-07	5,5083E-09
625	1	1	1	1	0,999984546	0,749221842	0,047054772	0,00045921	3,5037E-06	4,2274E-08
650	1	1	1	1	0,999999713	0,910539714	0,13219578	0,00224926	2,2042E-05	2,8665E-07
675	1	1	1	1	0,999999997	0,978106758	0,288409998	0,00895619	0,00011824	1,7181E-06
700	1	1	1	1	1	0,996407781	0,5	0,02911653	0,0005416	9,1076E-06
725	1	1	1	1	1	0,999610591	0,711590002	0,0777377	0,0021217	4,2726E-05
750	1	1	1	1	1	0,999972378	0,86780422	0,17182711	0,00712339	0,00017752
775	1	1	1	1	1	0,999998726	0,952945228	0,31793365	0,02055179	0,00065385
800	1	1	1	1	1	0,999999962	0,987197239	0,5	0,0511308	0,00213737
825	1	1	1	1	1	0,999999999	0,997366051	0,68206635	0,11019529	0,00620967
850	1	1	1	1	1	1	0,99959333	0,82817289	0,20696608	0,01606229
875	1	1	1	1	1	1	0,99995313	0,9222623	0,34145451	0,03707277
900	1	1	1	1	1	1	0,999995983	0,97088347	0,5	0,07656373
925	1	1	1	1	1	1	0,999999745	0,99104381	0,65854549	0,14198839
950	1	1	1	1	1	1	0,999999988	0,99775074	0,79303392	0,23752526
975	1	1	1	1	1	1	1	0,99954079	0,88980471	0,36049243
1000	1	1	1	1	1	1	1	0,99992403	0,9488692	0,5
1025	1	1	1	1	1	1	1	0,99998984	0,97944821	0,63950757
1050	1	1	1	1	1	1	1	0,9999989	0,99287661	0,76247474
1075	1	1	1	1	1	1	1	0,9999999	0,9978783	0,85801161
1100	1	1	1	1	1	1	1	0,99999999	0,9994584	0,92343627
1125	1	1	1	1	1	1	1	1	0,99988176	0,96292723
1150	1	1	1	1	1	1	1	1	0,99997796	0,98393771
1175	1	1	1	1	1	1	1	1	0,9999965	0,99379033
1200	1	1	1	1	1	1	1	1	0,99999953	0,99786263

Figure 25: First 10 years of distribution of additional daily bike users due to growth in population

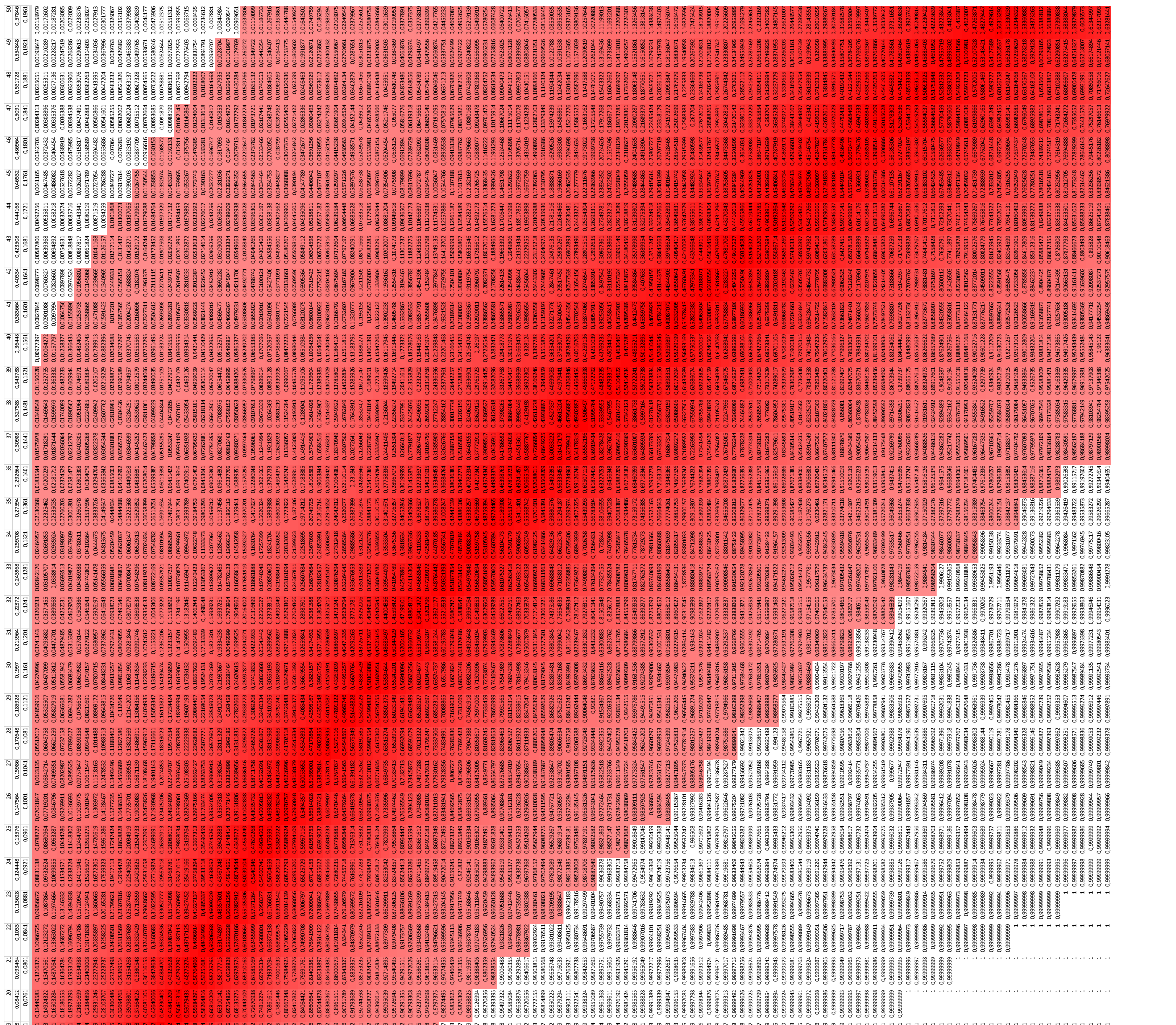

Figure 26: Distribution of probability of implementation of underground train station

Year	1	2	3	4	5	6	7	8	9	10
mu	0,000064	0,00006	0,000548	0,001528	0,003	0,004964	0,00742	0,010368	0,013808	0,01774
sigma	0,0001	0,0041	0,0081	0,0121	0,0161	0,0201	0,0241	0,0281	0,0321	0,0361
0	0,2610863	0,49416203	0,47303041	0,44975475	0,42609087	0,40246759	0,37908537	0,3560758	0,33354117	0,31156728
0,005	1	0,88587481	0,70871328	0,61292169	0,54943088	0,50071452	0,46000746	0,42425025	0,39189149	0,36207849
0,01	1	0,99233294	0,87837736	0,75808796	0,66813989	0,59891792	0,54262691	0,49477557	0,45278453	0,41511584
0,015	1	0,99986573	0,96280421	0,86722918	0,77196739	0,6912172	0,62343801	0,56546498	0,5148109	0,46974922
0,02	1	0,99999942	0,99183558	0,93657119	0,85449319	0,77278793	0,69916195	0,63411643	0,57648026	0,52495903
0,025	1	1	0,99873097	0,97380011	0,91410263	0,84057307	0,76714001	0,6987162	0,63632788	0,57969295
0,03	1	1	0,99986157	0,99069013	0,95323058	0,89353924	0,82560258	0,75761388	0,69301816	0,6329257
0,035	1	1	0,99998947	0,99716502	0,97657079	0,93245509	0,87377076	0,80964358	0,74543306	0,6837163
0,04	1	1	0,99999944	0,99926236	0,98922299	0,95934058	0,9117911	0,85417745	0,79273568	0,73125746
0,045	1	1	0,99999998	0,99983638	0,9954556	0,97680574	0,94054157	0,89111051	0,83440342	0,7749129
0,05	1	1	1	0,99996912	0,99824565	0,9874739	0,96136955	0,92078794	0,87022949	0,81423974
0,055	1	1	1	0,99999505	0,99938065	0,99360121	0,97582469	0,94389384	0,90029598	0,84899508
0,06	1	1	1	0,99999933	0,99980022	0,99691032	0,98543574	0,96132416	0,92492518	0,87912766
0,065	1	1	1	0,99999992	0,99994117	0,99859073	0,99155771	0,97406429	0,94461775	0,90475675
0,07	1	1	1	0,99999999	0,99998419	0,99939311	0,99529353	0,98308681	0,95998651	0,92614188
0,075	1	1	1	1	0,99999613	0,99975336	0,99747752	0,98927791	0,97169389	0,94364731
0,08	1	1	1	1	0,99999913	0,99990544	0,9987007	0,99339407	0,9803988	0,95770505
0,085	1	1	1	1	0,99999982	0,99996582	0,999357	0,99604565	0,98671642	0,96877997
0,09	1	1	1	1	0,99999997	0,99998835	0,99969436	0,99770066	0,99119177	0,97733945
0,095	1	1	1	1	0,99999999	0,99999626	0,99986048	0,99870155	0,99428623	0,98382933
0,1	1	1	1	1	1	0,99999887	0,99993886	0,99928802	0,99637469	0,98865667
0,105	1	1	1	1	1	0,99999968	0,99997428	0,99962099	0,99775048	0,99217924
0,11	1	1	1	1	1	0,99999991	0,99998961	0,99980416	0,99863512	0,99470095
0,115	1	1	1	1	1	0,99999998	0,99999598	0,99990178	0,99919033	0,99647193
0,12	1	1	1	1	1	0,99999999	0,9999985	0,9999522	0,99953045	0,99769207

Figure 27: First 10 years of distribution of probability of implementation of underground train station

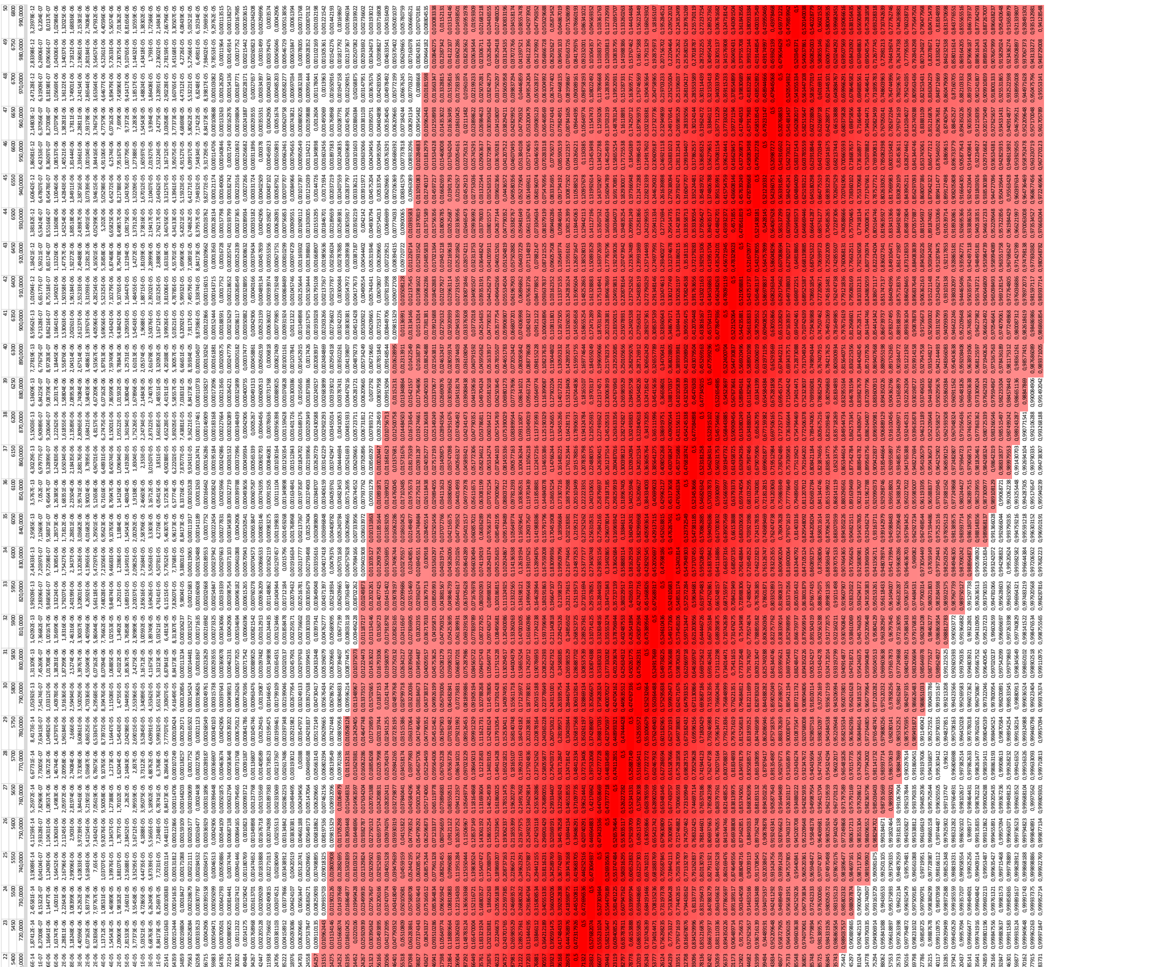

Figure 28: Distribution of reduction in daily car users after implementation of underground train station

Year	1	2	3	4	5	6	7	8	9	10
mu	2500	3500	4000	4500	4550	4600	4650	4700	4750	4800
sigma	500,0000	510,0000	520,0000	530,0000	540,0000	550,0000	560,0000	570,0000	580,0000	590,0000
0	2,86652E-07	3,37749E-12	7,22523E-15	1,0282E-17	1,78954E-17	3,04071E-17	5,05138E-17	8,21571E-17	1,30988E-16	2,04963E-16
2000	0,158655254	0,001634841	5,99932E-05	1,1968E-06	1,16641E-06	1,13778E-06	1,11081E-06	1,08537E-06	1,06134E-06	1,03861E-06
2050	0,184060125	0,002233591	8,84173E-05	1,8944E-06	1,8316E-06	1,77296E-06	1,71812E-06	1,66675E-06	1,61855E-06	1,57325E-06
2100	0,211855399	0,003024641	0,000129171	2,973E-06	2,8525E-06	2,74084E-06	2,63714E-06	2,54064E-06	2,45069E-06	2,36668E-06
2150	0,241963652	0,004059761	0,000187064	4,6258E-06	4,40596E-06	4,20356E-06	4,01682E-06	3,84416E-06	3,68421E-06	3,53574E-06
2200	0,274253118	0,005401311	0,000268549	7,1364E-06	6,74962E-06	6,39591E-06	6,07162E-06	5,77364E-06	5,49921E-06	5,24594E-06
2250	0,308537539	0,007123386	0,000382185	1,0916E-05	1,02553E-05	9,65483E-06	9,10765E-06	8,60777E-06	8,15001E-06	7,72987E-06
2300	0,344578258	0,00931279	0,000539202	1,6555E-05	1,54543E-05	1,44594E-05	1,35578E-05	1,27388E-05	1,19929E-05	1,13118E-05
2350	0,382088578	0,012069742	0,000754163	2,4896E-05	2,30989E-05	2,14843E-05	2,00292E-05	1,87142E-05	1,75226E-05	1,64401E-05
2400	0,420740291	0,01550818	0,001045746	3,7121E-05	3,42435E-05	3,16712E-05	2,93649E-05	2,7291E-05	2,54208E-05	2,37299E-05
2450	0,460172163	0,019755573	0,001437627	5,4883E-05	5,03521E-05	4,6322E-05	4,2726E-05	3,95075E-05	3,66185E-05	3,40181E-05
2500	0,5	0,024952094	0,001959461	8,0459E-05	7,3437E-05	6,72194E-05	6,16964E-05	5,6775E-05	5,23765E-05	4,84342E-05
2550	0,539827837	0,031249069	0,002647952	0,00011696	0,000106237	9,67815E-05	8,84173E-05	8,09949E-05	7,43881E-05	6,84898E-05
2600	0,579259709	0,038806605	0,003547972	0,0001686	0,000152444	0,000138257	0,000125757	0,000114706	0,000104907	9,61917E-05
2650	0,617911422	0,047790352	0,004713692	0,000241	0,000216982	0,000195968	0,00017752	0,000161269	0,000146909	0,000134181
2700	0,655421742	0,058367386	0,006209665	0,00034161	0,000306354	0,000275611	0,000248709	0,00022509	0,000204287	0,000185907
2750	0,691462461	0,070701254	0,0081118	0,00048018	0,00042906	0,000384614	0,000345839	0,000311896	0,000282089	0,00025583
2800	0,725746882	0,084946295	0,010508128	0,00066936	0,000596098	0,000532576	0,000477308	0,00042906	0,000386804	0,000349679
2850	0,758036348	0,1012414	0,013499286	0,00092533	0,000821542	0,000731768	0,000653847	0,000585988	0,0005267	0,000474738
2900	0,788144601	0,119703439	0,01719859	0,00126861	0,00112322	0,000997724	0,000889025	0,000794565	0,000712213	0,000640195
2950	0,815939875	0,140420646	0,02173162	0,00172489	0,001523466	0,001349898	0,001199833	0,001069665	0,000956398	0,000857535
3000	0,841344746	0,16344629	0,027235195	0,00232603	0,002049956	0,001812407	0,001607333	0,001429728	0,001275433	0,001140982
3050	0,864333939	0,188792988	0,033855668	0,00311098	0,002736602	0,002414823	0,002137367	0,001897383	0,001689176	0,001508004
3100	0,88493033	0,216428024	0,041746466	0,00412688	0,003624481	0,003193012	0,002821309	0,002500126	0,002221773	0,001979841
3150	0,903199515	0,24627001	0,05106485	0,00543003	0,004762777	0,004189994	0,003696848	0,00327103	0,002902293	0,00258209
3200	0,919243341	0,278187185	0,061967903	0,00708686	0,006209665	0,005456779	0,004808763	0,004249456	0,003765386	0,003345298
3250	0,933192799	0,311997578	0,074607796	0,00917471	0,008033118	0,007053141	0,006209665	0,005481756	0,004851933	0,004305565
3300	0,945200708	0,347471158	0,089126453	0,01178242	0,010311534	0,009048283	0,007960658	0,007021915	0,006209665	0,005505132
3350	0,955434537	0,384334003	0,105649774	0,01501057	0,013134146	0,01152131	0,010131863	0,008932096	0,007893712	0,006992915
3400	0,964069681	0,422274389	0,124281624	0,01897142	0,016601101	0,014561477	0,012802761	0,011283051	0,009967043	0,008824966
3450	0,97128344	0,460950577	0,145097872	0,02378823	0,020823165	0,018268107	0,016062286	0,014154322	0,012500758	0,011064813
3500	0,977249868	0,5	0,168140748	0,02959412	0,025920939	0,022750132	0,020008595	0,017634204	0,015574172	0,013783642
3550	0,982135579	0,539049423	0,193413861	0,03653023	0,03202355	0,028125183	0,024748484	0,021819394	0,019274661	0,017060279
3600	0,986096552	0,577725611	0,220878164	0,0447432	0,039266742	0,034518174	0,030396362	0,02681429	0,023697199	0,020980925
3650	0,98927589	0,615665997	0,250449177	0,05438198	0,047790352	0,042059347	0,037072766	0,032729877	0,028943564	0,025638605
3700	0,991802464	0,652528842	0,28199571	0,06559396	0,057735163	0,050881752	0,044902373	0,039682197	0,035121165	0,031132301
3750	0,993790335	0,688002422	0,31534026	0,07852042	0,069239158	0,061118178	0,054011517	0,047790352	0,042341473	0,037565727
3800	0,995338812	0,721812815	0,350261197	0,09329158	0,08243327	0,07289757	0,064525208	0,057174065	0,050718041	0,045045749
3850	0,996533026	0,75372999	0,386496734	0,11002125	0,097436712	0,086341021	0,076563726	0,067950813	0,060364122	0,05368043
3900	0,99744487	0,783571976	0,423750597	0,12880135	0,11435206	0,101557418	0,090238839	0,080232589	0,071389926	0,063576722
3950	0,998134187	0,811207012	0,461699193	0,14969653	0,133260263	0,118638926	0,105649774	0,094122357	0,083899544	0,074837841
4000	0,998650102	0,83655371	0,5	0,17273914	0,154215802	0,137656443	0,122879055	0,109710313	0,097987641	0,08756037
4050	0,999032397	0,859579354	0,538300807	0,1979249	0,177242238	0,158655254	0,141988386	0,127070075	0,113735993	0,101831165
4100	0,999312862	0,880296561	0,576249403	0,22520941	0,202328381	0,18165107	0,163014737	0,146254939	0,131209994	0,117724158
4150	0,999516576	0,8987586	0,613503266	0,25450585	0,229425326	0,206626688	0,18596684	0,167294375	0,150455266	0,135297164
4200	0,999663071	0,915053705	0,649738803	0,28568406	0,258444568	0,233529451	0,210822265	0,190190914	0,171494518	0,154588809
4250	0,999767371	0,929298746	0,68465974	0,31857114	0,289257361	0,262269718	0,237525262	0,214917602	0,194324784	0,175615712
4300	0,999840891	0,941632614	0,71800429	0,35295361	0,321695458	0,292720467	0,265985529	0,241416175	0,218915215	0,198370048
4350	0,9998922	0,952209648	0,749550823	0,38858119	0,355553274	0,324718142	0,296078014	0,269596071	0,245205531	0,222817627
4400	0,999927652	0,961193395	0,779121836	0,42517211	0,390591475	0,358064784	0,327643849	0,299334407	0,273105258	0,248896593
4450	0,999951904	0,968750931	0,806586139	0,46241969	0,426541894	0,392531434	0,360492431	0,33047697	0,302493835	0,276516851
4500	0,999968329	0,975047906	0,831859252	0,5	0,463113614	0,427862708	0,394404642	0,362840241	0,333221649	0,305560282
4550	0,999979342	0,980244427	0,854902128	0,53758031	0,5	0,463782413	0,429137115	0,396214441	0,365111996	0,3358818
4600	0,999986654	0,98449182	0,875718376	0,57482789	0,536886386	0,5	0,464427424	0,430367508	0,397963959	0,367311249
4650	0,99999146	0,987930258	0,894350226	0,61141881	0,573458106	0,536217587	0,5	0,46504989	0,431556115	0,399656122
4700	0,999994587	0,99068721	0,910873547	0,64704639	0,609408525	0,572137292	0,535572576	0,5	0,465650974	0,432705019
4750	0,999996602	0,992876614	0,925392204	0,68142886	0,644446726	0,607468566	0,570862885	0,53495011	0,5	0,466231757
4800	0,999997888	0,994598689	0,938032097	0,71431594	0,678304542	0,641935216	0,605595358	0,569632492	0,534349026	0,5
4850	0,999998699	0,995940239	0,94893515	0,74549415	0,710742639	0,675281858	0,639507569	0,603785559	0,568443885	0,533768243
4900	0,999999207	0,996975359	0,958253534	0,77479059	0,741555432	0,707279533	0,672356151	0,637159759	0,602036041	0,567294981
4950	0,999999521	0,997766409	0,966144332	0,8020751	0,770574674	0,737730282	0,703921986	0,66952303	0,634888004	0,600343878
5000	0,999999713	0,998365159	0,972764805	0,82726086	0,797671619	0,766470549	0,734014471	0,700665593	0,666778351	0,632688751
5050	0,99999983	0,998814025	0,97826838	0,85030347	0,822757762	0,793373312	0,762474738	0,730403929	0,697506165	0,6641182
5100	0,9999999	0,999147311	0,98280141	0,87119865	0,845784198	0,81834893	0,789177735	0,758583825	0,726894742	0,694439718
5150	0,999999942	0,999392413	0,986500714	0,88997875	0,866739737	0,841344746	0,81403316	0,785082398	0,754794469	0,723483149
5200	0,999999967	0,99957094	0,989491872	0,90670842	0,88564794	0,862343557	0,836985263	0,809809086	0,781084785	0,751103407
5250	0,999999981	0,999699732	0,9918882	0,92147958	0,902563288	0,881361074	0,858011614	0,832705625	0,805675216	0,777182373
5300	0,999999989	0,999791758	0,993790335	0,93440604	0,91756673	0,898442582	0,877120945	0,853745061	0,828505482	0,801629952
5350	0,999999994	0,999856883	0,995286308	0,94561802	0,930760842	0,913658979	0,894350226	0,872929925	0,849544734	0,824384288
5400	0,999999997	0,999902532	0,996452028	0,9552568	0,942264837	0,92710243	0,909761161	0,890289687	0,868790006	0,845411191
5450	0,999999998	0,999934223	0,997352048	0,96346977	0,952209648	0,938881822	0,923436274	0,905877643	0,886264007	0,864702836
5500	0,999999999	0,999956013	0,998040539	0,97040588	0,960733258	0,949118248	0,935474792	0,919767411	0,902012359	0,882275842
5550	0,999999999	0,999970852	0,998562373	0,97621177	0,96797645	0,957940653	0,945988483	0,932049187	0,916100456	0,898168835
5600	1	0,999980862	0,998954254	0,98102858	0,974079061	0,965481826	0,955097627	0,942825935	0,928610074	0,91243963
5650	1	0,999987549	0,999245837	0,98498943	0,979176835	0,971874817	0,962927234	0,952209648	0,939635878	0,925162159
5700	1	0,999991974	0,999460798	0,98821758	0,983398899	0,977249868	0,969603638	0,960317803	0,949281959	0,936423278
5750	1	0,999994873	0,999617815	0,99082529	0,986865854	0,981731893	0,975251516	0,967270123	0,957658527	0,94631957
5800	1	0,999996756	0,999731451	0,99291314	0,989688466	0,985438523	0,979991405	0,97318571	0,964878835	0,954954251
5850	1	0,999997966	0,999812936	0,99456997	0,991966882	0,98847869	0,983937714	0,978180606	0,971056436	0,962434273
5900	1	0,999998736	0,999870829	0,99587312	0,993790335	0,990951717	0,987197239	0,982365796	0,976302801	0,968867699
5950	1	0,999999222	0,999911583	0,99688902	0,995237223	0,992946859	0,989868137	0,985845678	0,980725339	0,974361395
6000	1	0,999999526	0,999940007	0,99767397	0,996375519	0,994543221	0,992039342	0,988716949	0,984425828	0,979019075
6050	1	0,999999713	0,999959649	0,99827511	0,997263398	0,995810006	0,993790335	0,991067904	0,987499242	0,982939721
6100	1	0,999999828	0,999973099	0,99873139	0,997950044	0,996806988	0,995191237	0,992978085	0,990032957	0,986216358
6150	1	0,999999898	0,999982223	0,99907467	0,998476534	0,997585177	0,996303152	0,994518244	0,992106288	0,988935187
6200	1	0,99999994	0,999988355	0,99933064	0,99887678	0,998187593	0,997178691	0,995750544	0,993790335	0,991175034

Figure 29: First 10 years of distribution of reduction in daily car users after implementation of underground train station

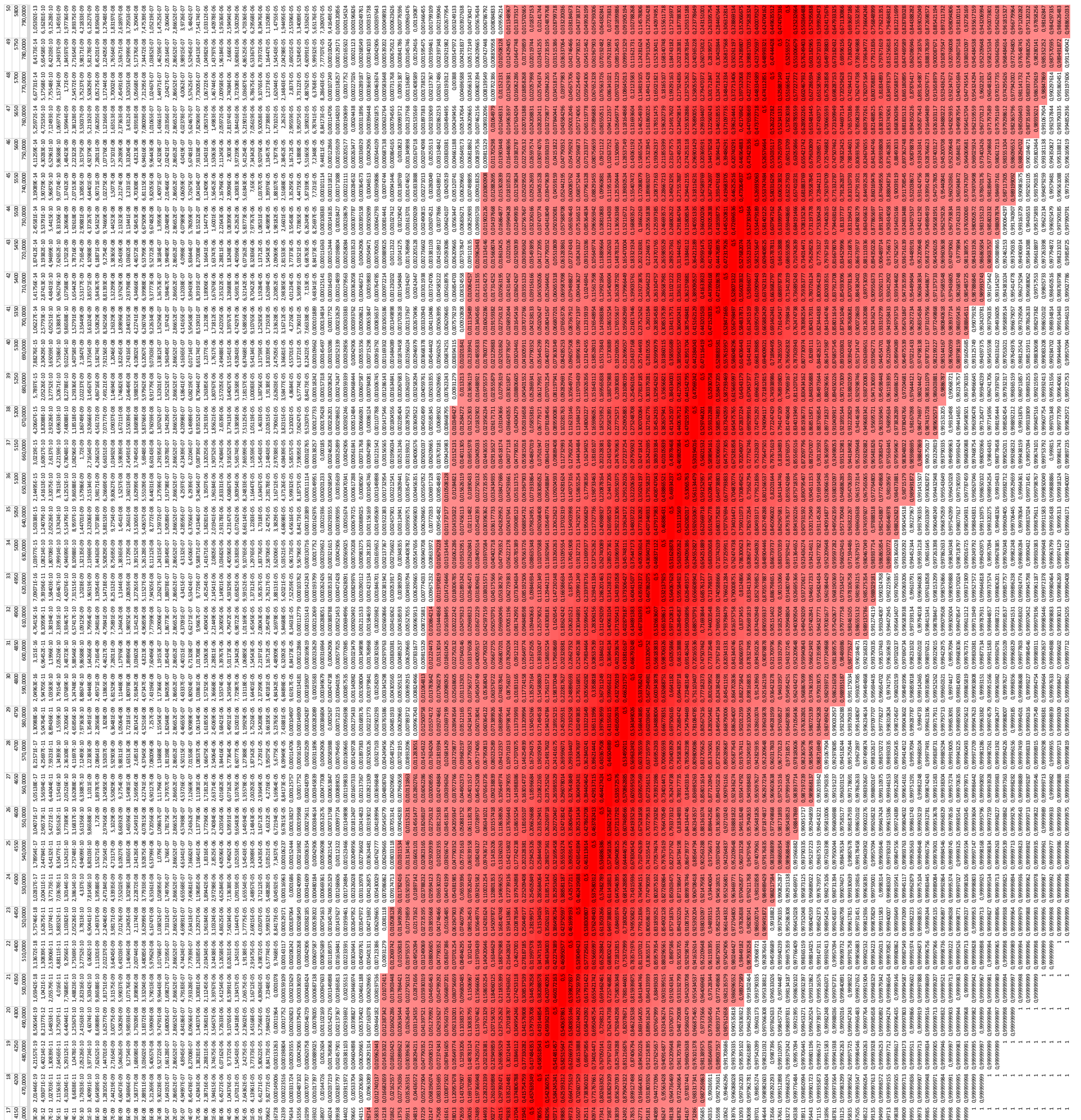

Figure 30: Distribution of additional daily bike users after implementation of underground train station

Year	1	2	3	4	5	6	7	8	9	10
mu	1500	2500	3000	3500	3550	3600	3650	3700	3750	3800
sigma	300,0000	310,0000	320,0000	330,0000	340,0000	350,0000	360,0000	370,0000	380,0000	390,0000
0	2,86652E-07	3,67632E-16	3,45879E-21	1,3964E-26	8,04027E-26	4,08669E-25	1,85649E-24	7,61985E-24	2,85278E-23	9,8244E-23
1000	0,047790352	6,53424E-07	2,05226E-10	1,7852E-14	3,19089E-14	5,48884E-14	9,11928E-14	1,46803E-13	2,29626E-13	3,49867E-13
1050	0,066807201	1,45254E-06	5,51479E-10	5,6714E-14	9,69461E-14	1,59985E-13	2,55724E-13	3,97072E-13	6,00467E-13	8,86384E-13
1100	0,09121122	3,14901E-06	1,44701E-09	1,7615E-13	2,88346E-13	4,57053E-13	7,03638E-13	1,0549E-12	1,54373E-12	2,20969E-12
1150	0,121672505	6,65825E-06	3,70738E-09	5,3491E-13	8,39591E-13	1,27981E-12	1,89976E-12	2,75276E-12	3,90189E-12	5,42044E-12
1200	0,158655254	1,37312E-05	9,2754E-09	1,5881E-12	2,39331E-12	3,51257E-12	5,033E-12	7,05574E-12	9,69618E-12	1,30839E-11
1250	0,202328381	2,76217E-05	2,2661E-08	4,61E-12	6,67901E-12	9,44948E-12	1,30839E-11	1,7764E-11	2,36895E-11	3,10774E-11
1300	0,252492538	5,42021E-05	5,40657E-08	1,3084E-11	1,82481E-11	2,49174E-11	3,33763E-11	4,39306E-11	5,69045E-11	7,26375E-11
1350	0,308537539	0,000103762	1,25972E-07	3,6308E-11	4,88111E-11	6,44044E-11	8,35477E-11	1,06716E-10	1,34393E-10	1,67067E-10
1400	0,36944134	0,000193799	2,86652E-07	9,8516E-11	1,27828E-10	1,63175E-10	2,05226E-10	2,54643E-10	3,1207E-10	3,7813E-10
1450	0,433816167	0,000353182	6,37056E-07	2,6137E-10	3,27752E-10	4,05251E-10	4,94699E-10	5,96875E-10	7,12493E-10	8,42203E-10
1500	0,5	0,000628091	1,38281E-06	6,7805E-10	8,22788E-10	9,86588E-10	1,17022E-09	1,37432E-09	1,59944E-09	1,84597E-09
1550	0,566183833	0,001090112	2,93178E-06	1,72E-09	2,02237E-09	2,35449E-09	2,71654E-09	3,10855E-09	3,53037E-09	3,98171E-09
1600	0,63055866	0,001846701	6,07162E-06	4,2665E-09	4,86716E-09	5,50829E-09	6,18871E-09	6,90711E-09	7,66205E-09	8,45201E-09
1650	0,691462461	0,003053917	1,2283E-05	1,0349E-08	1,14694E-08	1,26329E-08	1,38365E-08	1,5077E-08	1,63513E-08	1,76564E-08
1700	0,747507462	0,004930794	2,4275E-05	2,4549E-08	2,64649E-08	2,84035E-08	3,03602E-08	3,2331E-08	3,4312E-08	3,62999E-08
1750	0,797671619	0,007774033	4,68698E-05	5,6948E-08	5,97962E-08	6,26076E-08	6,53799E-08	6,81115E-08	7,08009E-08	7,34472E-08
1800	0,841344746	0,011970819	8,84173E-05	1,292E-07	1,32301E-07	1,35296E-07	1,38184E-07	1,40971E-07	1,43661E-07	1,46259E-07
1850	0,878327495	0,018006785	0,000162976	2,8665E-07	2,86652E-07	2,86652E-07	2,86652E-07	2,86652E-07	2,86652E-07	2,86652E-07
1900	0,90878878	0,026465473	0,000293555	6,2204E-07	6,08219E-07	5,95458E-07	5,83644E-07	5,72675E-07	5,62467E-07	5,52945E-07
1950	0,933192799	0,038015571	0,00051674	1,3202E-06	1,26385E-06	1,2128E-06	1,16641E-06	1,12409E-06	1,08537E-06	1,04982E-06
2000	0,952209648	0,053382767	0,000889025	2,7408E-06	2,57205E-06	2,42205E-06	2,28811E-06	2,16796E-06	2,05972E-06	1,96184E-06
2050	0,966623492	0,073304634	0,001495069	5,5657E-06	5,12658E-06	4,74297E-06	4,40596E-06	4,10833E-06	3,84416E-06	3,60861E-06
2100	0,977249868	0,09846934	0,002457901	1,1056E-05	1,00083E-05	9,10765E-06	8,32836E-06	7,65E-06	7,05619E-06	6,53367E-06
2150	0,98486986	0,129442113	0,003950751	2,1484E-05	1,9138E-05	1,71503E-05	1,54543E-05	1,39976E-05	1,27388E-05	1,16447E-05
2200	0,990184671	0,166586634	0,006209665	4,0844E-05	3,58477E-05	3,16712E-05	2,81533E-05	2,51688E-05	2,262E-05	2,04298E-05
2250	0,993790335	0,209991249	0,009545482	7,5969E-05	6,57774E-05	5,73601E-05	5,03521E-05	4,44735E-05	3,95075E-05	3,52845E-05
2300	0,996169619	0,259411334	0,014353022	0,00013826	0,000118242	0,000101889	8,84173E-05	7,7231E-05	6,78741E-05	5,99932E-05
2350	0,997696734	0,314238723	0,02111482	0,00024621	0,000208242	0,00017752	0,000152444	0,000131812	0,000114706	0,000100424
2400	0,998650102	0,373506427	0,030396362	0,00042906	0,000359339	0,000303383	0,000258084	0,000221111	0,000190699	0,000165502
2450	0,999229015	0,435932372	0,042829952	0,00073177	0,000607587	0,000508621	0,00042906	0,000364573	0,000311896	0,000268549
2500	0,99957094	0,5	0,059085123	0,00122154	0,001006745	0,000836537	0,000700501	0,000590886	0,000501875	0,00042906
2550	0,999767371	0,564067628	0,079824951	0,00199603	0,001634841	0,001349898	0,00112322	0,000941446	0,000794565	0,000675012
2600	0,999877134	0,626493573	0,105649774	0,00319301	0,002602077	0,002137367	0,001768968	0,001474652	0,001237768	0,001045746
2650	0,999936791	0,685761277	0,137032319	0,00500104	0,004059761	0,003320943	0,002736602	0,002271013	0,001897383	0,001595475
2700	0,999968329	0,740588666	0,174250712	0,00767018	0,006209665	0,005063995	0,004158912	0,003438912	0,002862253	0,002397348
2750	0,999984546	0,790008751	0,217327736	0,01152131	0,00931279	0,007579219	0,006209665	0,005120741	0,004249456	0,003547972
2800	0,999992657	0,833413366	0,265985529	0,01695198	0,013696119	0,011135489	0,009110135	0,007498895	0,006209665	0,005172149
2850	0,999996602	0,870557887	0,319624172	0,02443656	0,019755573	0,016062286	0,013134146	0,010800908	0,008932096	0,007427448
2900	0,999998469	0,90153066	0,377330282	0,03451817	0,02795319	0,022750132	0,018610425	0,015302839	0,012648331	0,010508128
2950	0,999999329	0,926695366	0,437917983	0,04779035	0,038806605	0,031645416	0,025920939	0,021329824	0,017634204	0,014647748
3000	0,999999713	0,946617233	0,5	0,06486702	0,052869341	0,043238133	0,035493895	0,029252693	0,024208831	0,020119744
3050	0,999999881	0,961984429	0,562082017	0,08634102	0,070701254	0,058041567	0,047790352	0,039479639	0,032729877	0,027235195
3100	0,999999952	0,973534527	0,622669718	0,11273299	0,092829691	0,076563726	0,063283861	0,052442195	0,043584296	0,036337064
3150	0,999999981	0,981993215	0,680375828	0,14443448	0,119703439	0,099271397	0,08243327	0,068575244	0,057174065	0,047790352
3200	0,999999993	0,988029181	0,734014471	0,18165107	0,151643112	0,126548954	0,105649774	0,088291455	0,073896883	0,061967903
3250	0,999999997	0,992225967	0,782672264	0,2243525	0,188792988	0,158655254	0,133260263	0,111951284	0,094122357	0,079231992
3300	0,999999999	0,995069206	0,825749288	0,27223725	0,231080195	0,195682969	0,165470004	0,139830524	0,118164868	0,099912329
3350	1	0,996946083	0,862967681	0,32471814	0,278187185	0,237525262	0,202328381	0,172088079	0,146254939	0,124281624
3400	1	0,998153299	0,894350226	0,38093338	0,329542623	0,283854583	0,243701765	0,208737163	0,178511475	0,152530411
3450	1	0,998909888	0,920175049	0,43978468	0,384334003	0,334117571	0,289257361	0,249623291	0,214917602	0,184743182
3500	1	0,999371909	0,940914877	0,5	0,441542795	0,387548481	0,33846112	0,294412155	0,255302886	0,220878164
3550	1	0,999646818	0,957170048	0,56021532	0,5	0,443201503	0,390591475	0,342589769	0,299334407	0,260753012
3600	1	0,999806201	0,969603638	0,61906662	0,558457205	0,5	0,444768976	0,393476168	0,346518555	0,30403844
3650	1	0,999896238	0,97888518	0,67528186	0,615665997	0,556798497	0,5	0,446252516	0,396214441	0,350261197
3700	1	0,999945798	0,985646978	0,72776275	0,670457377	0,612451519	0,555231024	0,5	0,447658669	0,398817035
3750	1	0,999972378	0,990454518	0,7756475	0,721812815	0,665882429	0,609408525	0,553747484	0,5	0,448993321
3800	1	0,999986269	0,993790335	0,81834893	0,768919805	0,716145417	0,66153888	0,606523832	0,552341331	0,5
3850	1	0,999993342	0,996049249	0,85556552	0,811207012	0,762474738	0,710742639	0,657410231	0,603785559	0,551006679
3900	1	0,999996851	0,997542099	0,88726701	0,848356888	0,804317031	0,756298235	0,705587845	0,653481445	0,601182965
3950	1	0,999998547	0,998504931	0,91365898	0,880296561	0,841344746	0,797671619	0,750376709	0,700665593	0,649738803
4000	1	0,999999347	0,999110975	0,93513298	0,907170309	0,873451046	0,834529996	0,791262837	0,744697114	0,69596156
4050	1	0,999999713	0,99948326	0,95220965	0,929298746	0,900728603	0,866739737	0,827911921	0,785082398	0,739246988
4100	1	0,999999877	0,999706445	0,96548183	0,947130659	0,923436274	0,894350226	0,860169476	0,821488525	0,779121836
4150	1	0,999999949	0,999837024	0,97556344	0,961193395	0,941958433	0,91756673	0,888048716	0,853745061	0,815256818
4200	1	0,999999979	0,999911583	0,98304802	0,97204681	0,956761867	0,936716139	0,911708545	0,881835132	0,847469589
4250	1	0,999999992	0,99995313	0,98847869	0,980244427	0,968354584	0,952209648	0,931424756	0,905877643	0,875718376
4300	1	0,999999997	0,999975725	0,99232982	0,986303881	0,977249868	0,964506105	0,947557805	0,926103117	0,900087671
4350	1	0,999999999	0,999987717	0,99499896	0,99068721	0,983937714	0,974079061	0,960520361	0,942825935	0,920768008
4400	1	1	0,999993928	0,99680699	0,993790335	0,988864511	0,981389575	0,970747307	0,956415704	0,938032097
4450	1	1	0,999997068	0,99800397	0,995940239	0,992420781	0,986865854	0,978670176	0,967270123	0,952209648
4500	1	1	0,999998617	0,99877846	0,997397923	0,994936005	0,990889865	0,984697161	0,975791169	0,963662936
4550	1	1	0,999999363	0,99926823	0,998365159	0,996679057	0,993790335	0,989199092	0,982365796	0,972764805
4600	1	1	0,999999713	0,99957094	0,998993255	0,997862633	0,995841088	0,992501105	0,987351669	0,979880256
4650	1	1	0,999999874	0,99975379	0,999392413	0,998650102	0,997263398	0,994879259	0,991067904	0,985352252
4700	1	1	0,999999946	0,99986174	0,999640661	0,999163463	0,998231032	0,996561088	0,993790335	0,989491872
4750	1	1	0,999999977	0,99992403	0,999791758	0,999491379	0,99887678	0,997728987	0,995750544	0,992572552

Figure 31: First 10 years of distribution of additional daily bike users after implementation of underground train station

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
mu	0,005	0,02	0,05	0,2	0,4	0,85	0,95	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001	1,00001
sigma	0,0050	0,0050	0,0050	0,0050	0,0050	0,0050	0,0050	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
0	0,158655254	3,16712E-05	7,61985E-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,005	0,5	0,001349898	1,12859E-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,01	0,841344746	0,022750132	6,22096E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,015	0,977249868	0,158655254	1,27981E-12	5,7256E-300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,02	0,998650102	0,5	9,86588E-10	4,1826E-284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,025	0,999968329	0,841344746	2,86652E-07	1,1249E-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,03	0,999999713	0,977249868	3,16712E-05	1,1139E-253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,035	0,999999999	0,998650102	0,001349898	4,0612E-239	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,04	1	0,999968329	0,022750132	5,4521E-225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,045	1	0,999999713	0,158655254	2,6953E-211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,05	1	0,999999999	0,5	4,9067E-198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,055	1	1	0,841344746	3,2898E-185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,06	1	1	0,977249868	8,1239E-173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,065	1	1	0,998650102	7,3895E-161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,07	1	1	0,999968329	2,4761E-149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,075	1	1	0,999999713	3,0567E-138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,08	1	1	0,999999999	1,3904E-127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,085	1	1	1	2,3306E-117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,09	1	1	1	1,4399E-107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,095	1	1	1	3,27928E-98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,1	1	1	1	2,75362E-89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,105	1	1	1	8,52722E-81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,11	1	1	1	9,74095E-73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,115	1	1	1	4,106E-65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,12	1	1	1	6,38875E-58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,125	1	1	1	3,67097E-51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,13	1	1	1	7,79354E-45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,135	1	1	1	6,11716E-39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,14	1	1	1	1,77648E-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,145	1	1	1	1,91066E-28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,15	1	1	1	7,61985E-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,155	1	1	1	1,12859E-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,16	1	1	1	6,22096E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,165	1	1	1	1,27981E-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,17	1	1	1	9,86588E-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,175	1	1	1	2,86652E-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,18	1	1	1	3,16712E-05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,185	1	1	1	0,001349898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,19	1	1	1	0,022750132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,195	1	1	1	0,158655254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,2	1	1	1	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,205	1	1	1	0,841344746	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,21	1	1	1	0,977249868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,215	1	1	1	0,998650102	5,7256E-300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,22	1	1	1	0,999968329	4,1826E-284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,225	1	1	1	0,999999713	1,1249E-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,23	1	1	1	0,999999999	1,1139E-253	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,235	1	1	1	1	4,0612E-239	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,24	1	1	1	1	5,4521E-225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,245	1	1	1	1	2,6953E-211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,25	1	1	1	1	4,9067E-198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,255	1	1	1	1	3,2898E-185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,26	1	1	1	1	8,1239E-173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,265	1	1	1	1	7,3895E-161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,27	1	1	1	1	2,4761E-149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,275	1	1	1	1	3,0567E-138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,28	1	1	1	1	1,3904E-127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,285	1	1	1	1	2,3306E-117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,29	1	1	1	1	1,4399E-107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,295	1	1	1	1	3,27928E-98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,3	1	1	1	1	2,75362E-89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,305	1	1	1	1	8,52722E-81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,31	1	1	1	1	9,74095E-73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,315	1	1	1	1	4,106E-65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,32	1	1	1	1	6,38875E-58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,325	1	1	1	1	3,67097E-51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,33	1	1	1	1	7,79354E-45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,335	1	1	1	1	6,11716E-39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,34	1	1	1	1	1,77648E-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,345	1	1	1	1	1,91066E-28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,35	1	1	1	1	7,61985E-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,355	1	1	1	1	1,12859E-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,36	1	1	1	1	6,22096E-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,365	1	1	1	1	1,27981E-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,37	1	1	1	1	9,86588E-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,375	1	1	1	1	2,86652E-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,38	1	1	1	1	3,16712E-05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,385	1	1	1	1	0,001349898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,39	1	1	1	1	0,022750132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,395	1	1	1	1	0,158655254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,4	1	1	1	1	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,405	1	1	1	1	0,841344746	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,41	1	1	1	1	0,977249868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,415	1	1	1	1	0,998650102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,42	1	1	1	1	0,999968329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,425	1	1	1	1	0,999999713	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,43	1	1	1	1	0,999999999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,435	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,44	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,445	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,45	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,455	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,46	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 32: Distribution of probability of implementation of hospital expansion

Year	1	2	3	4	5	6	7	8	9	10
mu	0,005	0,02	0,05	0,2	0,4	0,85	0,95	1,00001	1,00001	1,00001
sigma	0,0050	0,0050	0,0050	0,0050	0,0050	0,0050	0,0050	0,0000	0,0000	0,0000
0	0,158655254	3,16712E-05	7,61985E-24	0	0	0	0	0	0	0
0,005	0,5	0,001349898	1,12859E-19	0	0	0	0	0	0	0
0,01	0,841344746	0,022750132	6,22096E-16	0	0	0	0	0	0	0
0,015	0,977249868	0,158655254	1,27981E-12	5,7256E-300	0	0	0	0	0	0
0,02	0,998650102	0,5	9,86588E-10	4,1826E-284	0	0	0	0	0	0
0,025	0,999968329	0,841344746	2,86652E-07	1,1249E-268	0	0	0	0	0	0
0,03	0,999999713	0,977249868	3,16712E-05	1,1139E-253	0	0	0	0	0	0
0,035	0,999999999	0,998650102	0,001349898	4,0612E-239	0	0	0	0	0	0
0,04	1	0,999968329	0,022750132	5,4521E-225	0	0	0	0	0	0
0,045	1	0,999999713	0,158655254	2,6953E-211	0	0	0	0	0	0
0,05	1	0,999999999	0,5	4,9067E-198	0	0	0	0	0	0
0,055	1	1	0,841344746	3,2898E-185	0	0	0	0	0	0
0,06	1	1	0,977249868	8,1239E-173	0	0	0	0	0	0
0,065	1	1	0,998650102	7,3895E-161	0	0	0	0	0	0
0,07	1	1	0,999968329	2,4761E-149	0	0	0	0	0	0
0,075	1	1	0,999999713	3,0567E-138	0	0	0	0	0	0
0,08	1	1	0,999999999	1,3904E-127	0	0	0	0	0	0
0,085	1	1	1	2,3306E-117	0	0	0	0	0	0
0,09	1	1	1	1,4399E-107	0	0	0	0	0	0
0,095	1	1	1	3,27928E-98	0	0	0	0	0	0
0,1	1	1	1	2,75362E-89	0	0	0	0	0	0
0,105	1	1	1	8,52722E-81	0	0	0	0	0	0
0,11	1	1	1	9,74095E-73	0	0	0	0	0	0
0,115	1	1	1	4,106E-65	0	0	0	0	0	0
0,12	1	1	1	6,38875E-58	0	0	0	0	0	0
0,125	1	1	1	3,67097E-51	0	0	0	0	0	0
0,13	1	1	1	7,79354E-45	0	0	0	0	0	0
0,135	1	1	1	6,11716E-39	0	0	0	0	0	0
0,14	1	1	1	1,77648E-33	0	0	0	0	0	0
0,145	1	1	1	1,91066E-28	0	0	0	0	0	0
0,15	1	1	1	7,61985E-24	0	0	0	0	0	0
0,155	1	1	1	1,12859E-19	0	0	0	0	0	0
0,16	1	1	1	6,22096E-16	0	0	0	0	0	0
0,165	1	1	1	1,27981E-12	0	0	0	0	0	0
0,17	1	1	1	9,86588E-10	0	0	0	0	0	0
0,175	1	1	1	2,86652E-07	0	0	0	0	0	0
0,18	1	1	1	3,16712E-05	0	0	0	0	0	0
0,185	1	1	1	0,001349898	0	0	0	0	0	0
0,19	1	1	1	0,022750132	0	0	0	0	0	0
0,195	1	1	1	0,158655254	0	0	0	0	0	0
0,2	1	1	1	0,5	0	0	0	0	0	0
0,205	1	1	1	0,841344746	0	0	0	0	0	0
0,21	1	1	1	0,977249868	0	0	0	0	0	0
0,215	1	1	1	0,998650102	5,7256E-300	0	0	0	0	0
0,22	1	1	1	0,999968329	4,1826E-284	0	0	0	0	0
0,225	1	1	1	0,999999713	1,1249E-268	0	0	0	0	0
0,23	1	1	1	0,999999999	1,1139E-253	0	0	0	0	0
0,235	1	1	1	1	4,0612E-239	0	0	0	0	0
0,24	1	1	1	1	5,4521E-225	0	0	0	0	0
0,245	1	1	1	1	2,6953E-211	0	0	0	0	0
0,25	1	1	1	1	4,9067E-198	0	0	0	0	0
0,255	1	1	1	1	3,2898E-185	0	0	0	0	0
0,26	1	1	1	1	8,1239E-173	0	0	0	0	0
0,265	1	1	1	1	7,3895E-161	0	0	0	0	0
0,27	1	1	1	1	2,4761E-149	0	0	0	0	0
0,275	1	1	1	1	3,0567E-138	0	0	0	0	0
0,28	1	1	1	1	1,3904E-127	0	0	0	0	0
0,285	1	1	1	1	2,3306E-117	0	0	0	0	0
0,29	1	1	1	1	1,4399E-107	0	0	0	0	0
0,295	1	1	1	1	3,27928E-98	0	0	0	0	0
0,3	1	1	1	1	2,75362E-89	0	0	0	0	0
0,305	1	1	1	1	8,52722E-81	0	0	0	0	0
0,31	1	1	1	1	9,74095E-73	0	0	0	0	0
0,315	1	1	1	1	4,106E-65	0	0	0	0	0
0,32	1	1	1	1	6,38875E-58	0	0	0	0	0
0,325	1	1	1	1	3,67097E-51	0	0	0	0	0
0,33	1	1	1	1	7,79354E-45	0	0	0	0	0
0,335	1	1	1	1	6,11716E-39	0	0	0	0	0
0,34	1	1	1	1	1,77648E-33	0	0	0	0	0
0,345	1	1	1	1	1,91066E-28	0	0	0	0	0
0,35	1	1	1	1	7,61985E-24	0	0	0	0	0
0,355	1	1	1	1	1,12859E-19	0	0	0	0	0
0,36	1	1	1	1	6,22096E-16	0	0	0	0	0
0,365	1	1	1	1	1,27981E-12	0	0	0	0	0
0,37	1	1	1	1	9,86588E-10	0	0	0	0	0
0,375	1	1	1	1	2,86652E-07	0	0	0	0	0
0,38	1	1	1	1	3,16712E-05	0	0	0	0	0
0,385	1	1	1	1	0,001349898	0	0	0	0	0
0,39	1	1	1	1	0,022750132	0	0	0	0	0
0,395	1	1	1	1	0,158655254	0	0	0	0	0
0,4	1	1	1	1	0,5	0	0	0	0	0
0,405	1	1	1	1	0,841344746	0	0	0	0	0
0,41	1	1	1	1	0,977249868	0	0	0	0	0
0,415	1	1	1	1	0,998650102	0	0	0	0	0
0,42	1	1	1	1	0,999968329	0	0	0	0	0
0,425	1	1	1	1	0,999999713	0	0	0	0	0
0,43	1	1	1	1	0,999999999	0	0	0	0	0

Figure 33: First 10 years of distribution of probability of implementation of hospital expansion

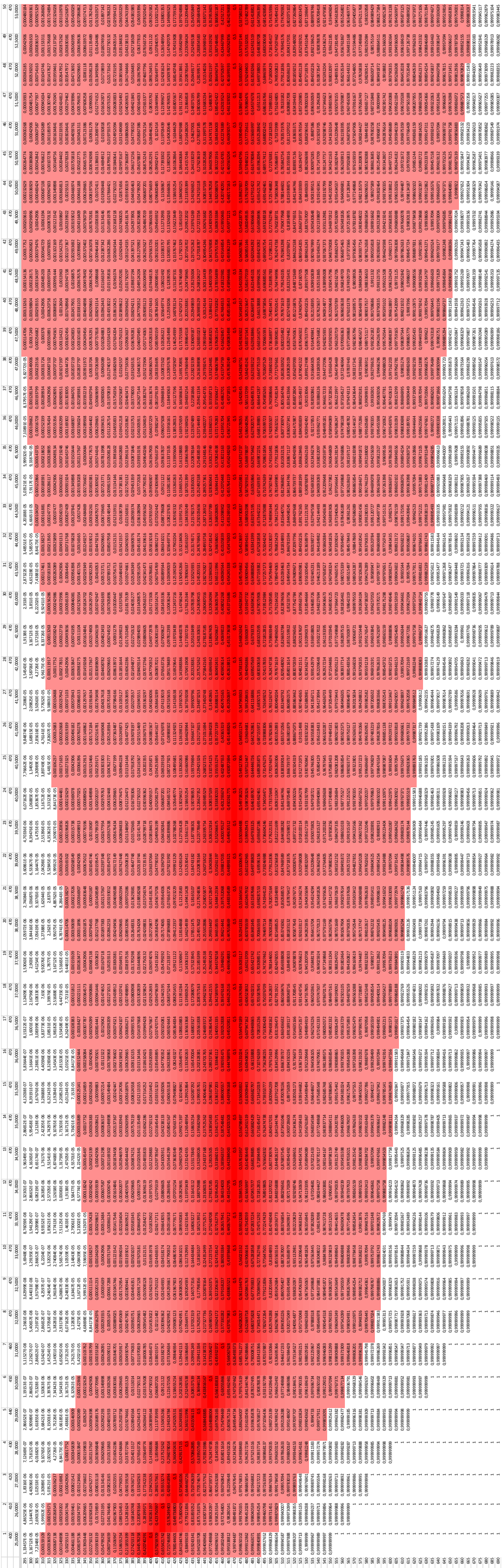

Figure 34: Distribution of additional daily car users after implementation of hospital expansion

Year	1	2	3	4	5	6	7	8	9	10
mu	400	410	420	430	440	450	460	470	470	470
sigma	25,0000	26,0000	27,0000	28,0000	29,0000	30,0000	31,0000	32,0000	32,5000	33,0000
295	1,33457E-05	4,86525E-06	1,8316E-06	7,12669E-07	2,86652E-07	1,19153E-07	5,11527E-08	2,2661E-08	3,62999E-08	5,6948E-08
300	3,16712E-05	1,16447E-05	4,40596E-06	1,71812E-06	6,90989E-07	2,86652E-07	1,22627E-07	5,40657E-08	8,44031E-08	1,29195E-07
305	7,2348E-05	2,69015E-05	1,02553E-05	4,01682E-06	1,61855E-06	6,71328E-07	2,86652E-07	1,25972E-07	1,91798E-07	2,86652E-07
310	0,000159109	5,99932E-05	2,30989E-05	9,10765E-06	3,68421E-06	1,53063E-06	6,53424E-07	2,86652E-07	4,2597E-07	6,2204E-07
315	0,000336929	0,000129171	5,03521E-05	2,00292E-05	8,15001E-06	3,39767E-06	1,45254E-06	6,37056E-07	9,24654E-07	1,32025E-06
320	0,000687138	0,000268549	0,000106237	4,2726E-05	1,75226E-05	7,34342E-06	3,14901E-06	1,38281E-06	1,96184E-06	2,74084E-06
325	0,001349898	0,000539202	0,000216982	8,84173E-05	3,66185E-05	1,54543E-05	6,65825E-06	2,93178E-06	4,06867E-06	5,56574E-06
330	0,00255513	0,001045746	0,00042906	0,00017752	7,43881E-05	3,16712E-05	1,37312E-05	6,07162E-06	8,24833E-06	1,10559E-05
335	0,004661188	0,001959461	0,000821542	0,000345839	0,000146909	6,32092E-05	2,76217E-05	1,2283E-05	1,63467E-05	2,14843E-05
340	0,008197536	0,003547972	0,001523466	0,000653847	0,000282089	0,000122866	5,42021E-05	2,4275E-05	3,16712E-05	4,08439E-05
345	0,013903448	0,006209665	0,002736602	0,001199833	0,0005267	0,000232629	0,000103762	4,68698E-05	5,99932E-05	7,59695E-05
350	0,022750132	0,010508128	0,004762777	0,002137367	0,000956398	0,00042906	0,000193799	8,84173E-05	0,000111114	0,000138257
355	0,035930319	0,01719859	0,008033118	0,003696848	0,001689176	0,000770985	0,000353182	0,000162976	0,000201233	0,000246208
360	0,054799292	0,027235195	0,013134146	0,006209665	0,002902293	0,001349898	0,000628091	0,000293555	0,00035639	0,00042906
365	0,080756659	0,041746466	0,020823165	0,010131863	0,004851933	0,002303266	0,001090112	0,00051674	0,000617288	0,000731768
370	0,11506967	0,061967903	0,03202355	0,016062286	0,007893712	0,003830381	0,001846701	0,000889025	0,001045746	0,001221542
375	0,158655254	0,089126453	0,047790352	0,024748484	0,012500758	0,006209665	0,003053917	0,001495069	0,001732954	0,001996034
380	0,211855399	0,124281624	0,069239158	0,037072766	0,019274661	0,009815329	0,004930794	0,002457901	0,002809441	0,003193012
385	0,274253118	0,168140748	0,097436712	0,054011517	0,028943564	0,01513014	0,007774033	0,003950751	0,004456351	0,005001037
390	0,344578258	0,220878164	0,133260263	0,076563726	0,042341473	0,022750132	0,011970819	0,006209665	0,006917128	0,007670181
395	0,420740291	0,28199571	0,177242238	0,105649774	0,060364122	0,033376508	0,018006785	0,009545482	0,010508128	0,01152131
400	0,5	0,350261197	0,229425326	0,141988386	0,083899544	0,047790352	0,026465473	0,014353022	0,015626119	0,016951978
405	0,579259709	0,423750597	0,289257361	0,18596684	0,113735993	0,066807201	0,038015571	0,02111482	0,022750132	0,024436555
410	0,655421742	0,5	0,355553274	0,237525262	0,150455266	0,09121122	0,053382767	0,030396362	0,032434935	0,034518174
415	0,725746882	0,576249403	0,426541894	0,296078014	0,194324784	0,121672505	0,073304634	0,042829952	0,045293661	0,047790352
420	0,788144601	0,649738803	0,5	0,360492431	0,245205531	0,158655254	0,09846934	0,059085123	0,061967903	0,064867019
425	0,841344746	0,71800429	0,573458106	0,429137115	0,302493835	0,202328381	0,129442113	0,079824951	0,083085052	0,086341021
430	0,88493033	0,779121836	0,644446726	0,5	0,365111996	0,252492538	0,166586634	0,105649774	0,109204593	0,112732993
435	0,919243341	0,831859252	0,710742639	0,570862885	0,431556115	0,308537539	0,209991249	0,137032319	0,140757316	0,144434484
440	0,945200708	0,875718376	0,770574674	0,639507569	0,5	0,36944134	0,259411334	0,174250712	0,17798356	0,18165107
445	0,964069681	0,910873547	0,822757762	0,703921986	0,568443885	0,433816167	0,314238723	0,217327736	0,220878164	0,224352499
450	0,977249868	0,938032097	0,866739737	0,762474738	0,634888004	0,5	0,373506427	0,265985529	0,269150375	0,272237254
455	0,986096552	0,958253534	0,902563288	0,81403316	0,697506165	0,566183833	0,435932372	0,319624172	0,322206167	0,324718142
460	0,991802464	0,972764805	0,930760842	0,858011614	0,754794469	0,63055866	0,5	0,377330282	0,379158237	0,380933384
465	0,995338812	0,98280141	0,952209648	0,894350226	0,805675216	0,691462461	0,564067628	0,437917983	0,438865521	0,43978468
470	0,99744487	0,989491872	0,96797645	0,923436274	0,849544734	0,747507462	0,626493573	0,5	0,5	0,5
475	0,998650102	0,993790335	0,979176835	0,945988483	0,886264007	0,797671619	0,685761277	0,562082017	0,561134479	0,56021532
480	0,999312862	0,996452028	0,986865854	0,962927234	0,916100456	0,841344746	0,740588666	0,622669718	0,620841763	0,619066616
485	0,999663071	0,998040539	0,991966882	0,975251516	0,939635878	0,878327495	0,790008751	0,680375828	0,677793833	0,675281858
490	0,999840891	0,998954254	0,995237223	0,983937714	0,957658527	0,90878878	0,833413366	0,734014471	0,730849625	0,727762746
495	0,999927652	0,999460798	0,997263398	0,989868137	0,971056436	0,933192799	0,870557887	0,782672264	0,779121836	0,775647501
500	0,999968329	0,999731451	0,998476534	0,993790335	0,980725339	0,952209648	0,90153066	0,825749288	0,82201644	0,81834893
505	0,999986654	0,999870829	0,999178458	0,996303152	0,987499242	0,966623492	0,926695366	0,862967681	0,859242684	0,855565516
510	0,999994587	0,999940007	0,99957094	0,997862633	0,992106288	0,977249868	0,946617233	0,894350226	0,890795407	0,887267007
515	0,999997888	0,999973099	0,999783018	0,998800167	0,995148067	0,98486986	0,961984429	0,920175049	0,916914948	0,913658979
520	0,999999207	0,999988355	0,999893763	0,999346153	0,997097707	0,990184671	0,973534527	0,940914877	0,938032097	0,935132981
525	0,999999713	0,999995135	0,999949648	0,999654161	0,998310824	0,993790335	0,981993215	0,957170048	0,954706339	0,952209648
530	0,9999999	0,999998038	0,999976901	0,99982248	0,999043602	0,996169619	0,988029181	0,969603638	0,967565065	0,965481826
535	0,999999967	0,999999237	0,999989745	0,999911583	0,9994733	0,997696734	0,992225967	0,97888518	0,977249868	0,975563445
540	0,999999989	0,999999713	0,999995594	0,999957274	0,999717911	0,998650102	0,995069206	0,985646978	0,984373881	0,983048022
545	0,999999997	0,999999896	0,999998168	0,999979971	0,999853091	0,999229015	0,996946083	0,990454518	0,989491872	0,98847869
550	0,999999999	0,999999964	0,999999263	0,999990892	0,999925612	0,99957094	0,998153299	0,993790335	0,993082872	0,992329819
555	1	0,999999988	0,999999713	0,999995983	0,999963382	0,999767371	0,998909888	0,996049249	0,995543649	0,994998963
560	1	0,999999996	0,999999892	0,999998282	0,999982477	0,999877134	0,999371909	0,997542099	0,997190559	0,996806988
565	1	0,999999999	0,999999961	0,999999287	0,99999185	0,999936791	0,999646818	0,998504931	0,998267046	0,998003966
570	1	1	0,999999986	0,999999713	0,999996316	0,999968329	0,999806201	0,999110975	0,998954254	0,998778458
575	1	1	0,999999995	0,999999888	0,999998381	0,999984546	0,999896238	0,99948326	0,999382712	0,999268232
580	1	1	0,999999998	0,999999958	0,999999309	0,999992657	0,999945798	0,999706445	0,99964361	0,99957094
585	1	1	1	0,999999985	0,999999713	0,999996602	0,999972378	0,999837024	0,999798767	0,999753792
590	1	1	1	0,999999994	0,999999884	0,999998469	0,999986269	0,999911583	0,999888886	0,999861743
595	1	1	1	0,999999998	0,999999955	0,999999329	0,999993342	0,99995313	0,999940007	0,999924031
600	1	1	1	0,999999999	0,999999983	0,999999713	0,999996851	0,999975725	0,999968329	0,999959156

Figure 35: First 10 years of distribution of additional daily car users after implementation of hospital expansion

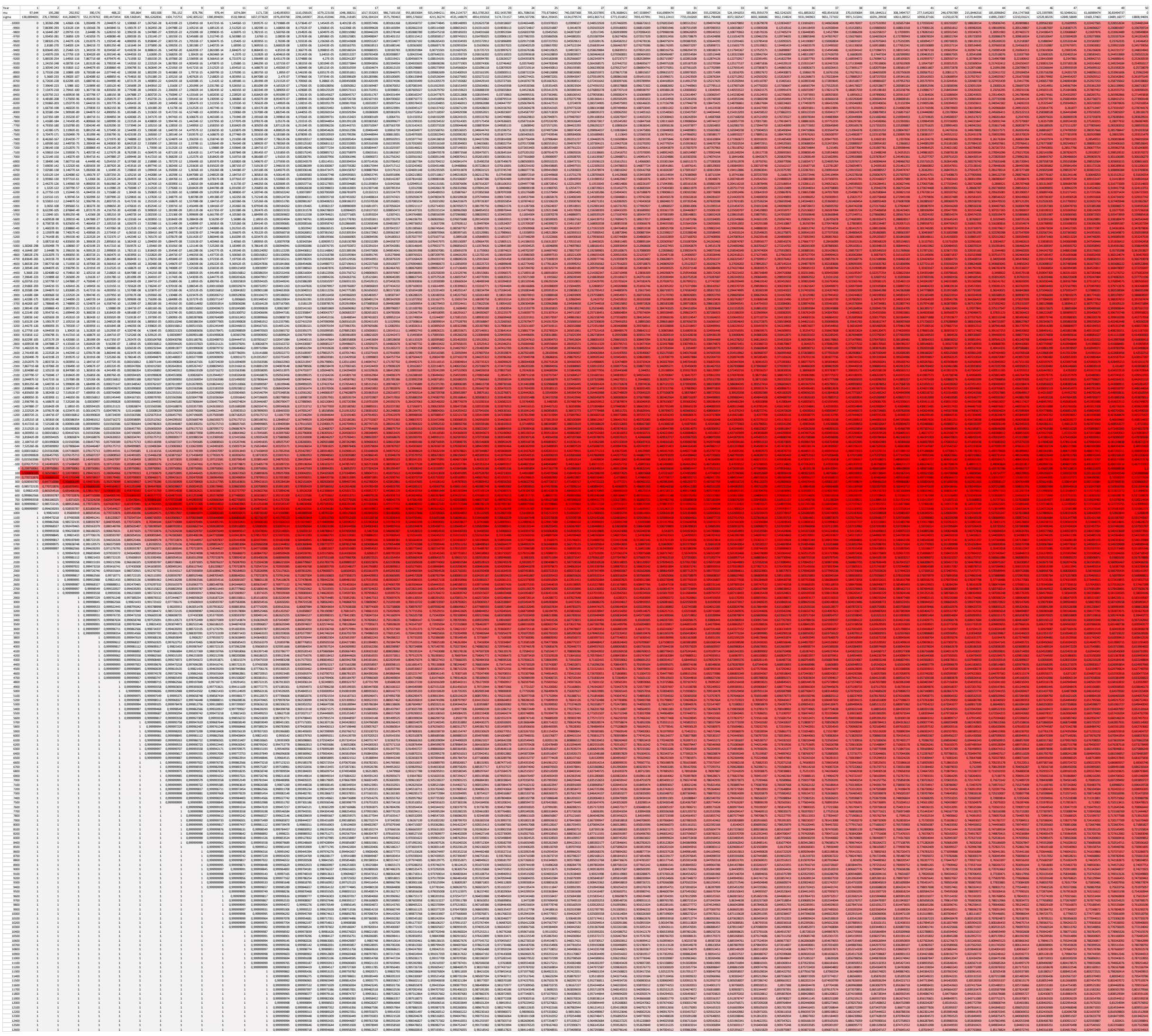

Figure 36: Distribution of variation in daily car users due to increase in use of autonomous vehicles

Year	1	2	3	4	5	6	7	8	9	10
mu	97,644	195,288	292,932	390,576	488,22	585,864	683,508	781,152	878,796	976,44
sigma	138,0894691	276,1789382	414,2684073	552,3578763	690,4473454	828,5368145	966,6262836	1104,715753	1242,805222	1380,894691
-2000	2,04487E-52	9,41721E-16	1,55708E-08	7,52526E-06	0,000156812	0,000901188	0,002750267	0,005909092	0,010269054	0,015563586
-1900	9,89125E-48	1,64072E-14	5,99969E-08	1,68499E-05	0,000271147	0,001348542	0,003762107	0,007611997	0,012678955	0,018624412
-1800	2,83886E-43	2,51252E-13	2,18471E-07	3,65653E-05	0,000459673	0,001990828	0,005095893	0,009732984	0,015563586	0,022183359
-1700	4,83565E-39	3,38243E-12	7,51913E-07	7,69095E-05	0,000764089	0,002899666	0,006835364	0,012353151	0,018994193	0,026299859
-1600	4,89005E-35	4,00395E-11	2,44635E-06	0,000156812	0,001245449	0,004167101	0,009079785	0,015563586	0,023047798	0,031036364
-1500	2,93679E-31	4,16867E-10	7,52526E-06	0,00030997	0,001990828	0,005909092	0,011944935	0,019465185	0,027806644	0,036457765
-1400	1,04788E-27	3,81842E-09	2,1891E-05	0,000594105	0,003121121	0,00826874	0,015563586	0,024168076	0,033357393	0,042630653
-1300	2,22252E-24	3,07817E-08	6,02347E-05	0,001104273	0,004799576	0,01141888	0,02008529	0,029790599	0,039790063	0,049622449
-1200	2,80372E-21	2,18471E-07	0,000156812	0,001990828	0,00724039	0,015563586	0,025675314	0,036457765	0,047196695	0,057500389
-1100	2,10521E-18	1,36581E-06	0,000386354	0,003481912	0,010716272	0,020938095	0,032512562	0,044299192	0,055669749	0,066330373
-1000	9,41721E-16	7,52526E-06	0,000901188	0,005909092	0,015563586	0,027806644	0,040786363	0,053446487	0,065300251	0,076175713
-900	2,51252E-13	3,65653E-05	0,001990828	0,009732984	0,022183359	0,036457765	0,050692059	0,064030104	0,076175713	0,087095772
-800	4,00395E-11	0,000156812	0,004167101	0,015563586	0,031036364	0,047196695	0,062425381	0,076175713	0,088377858	0,099144541
-700	3,81842E-09	0,000594105	0,00826874	0,024168076	0,042630653	0,060334741	0,076175713	0,090000177	0,101980224	0,112369182
-600	2,18471E-07	0,001990828	0,015563586	0,036457765	0,057500389	0,076175713	0,092118398	0,105607237	0,117045685	0,126808563
-500	7,52526E-06	0,005909092	0,027806644	0,053446487	0,076175713	0,094999805	0,110406384	0,123083063	0,133623993	0,142491835
-400	0,000156812	0,015563586	0,047196695	0,076175713	0,099144541	0,117045685	0,13116156	0,142491835	0,151749399	0,159437097
-300	0,001990828	0,036457765	0,076175713	0,105607237	0,126808563	0,142491835	0,154466238	0,163871567	0,171438459	0,177650176
-200	0,015563586	0,076175713	0,117045685	0,142491835	0,159437097	0,171438459	0,180355276	0,18723035	0,192688122	0,197123581
-100	0,076175713	0,142491835	0,171438459	0,18723035	0,197123581	0,203891469	0,208809376	0,212543256	0,21547416	0,217835671
0	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061	0,239750061
100	0,506806185	0,365038657	0,320708903	0,299421615	0,286964966	0,278799313	0,27303679	0,268753995	0,265446425	0,262815321
200	0,770722876	0,506806185	0,411251048	0,365038657	0,338178481	0,320708903	0,308466571	0,299421615	0,292470928	0,286964966
300	0,928593787	0,647710088	0,506806185	0,434873191	0,392578099	0,365038657	0,345776286	0,331583909	0,320708903	0,312117785
400	0,985722135	0,770722876	0,601970491	0,506806185	0,449164612	0,411251048	0,384647806	0,365038657	0,350024525	0,338178481
500	0,99821433	0,865054516	0,691406196	0,578517937	0,506806185	0,458730182	0,424715769	0,399554008	0,380262621	0,365038657
600	0,999862566	0,928593787	0,770722876	0,647710088	0,564305745	0,506806185	0,465577723	0,434873191	0,411251048	0,392578099
700	0,999993558	0,966186325	0,8371025	0,712324238	0,620475049	0,55478341	0,506806185	0,470720188	0,442803592	0,420666364
800	0,999999817	0,985722135	0,889525466	0,770722876	0,674207837	0,601970491	0,547962005	0,506806185	0,474723305	0,449164612
900	0,999999997	0,994639293	0,928593787	0,821806546	0,724544627	0,647710088	0,588608353	0,542836531	0,506806185	0,477927657
1000	1	0,99821433	0,95606919	0,865054516	0,770722876	0,691406196	0,628324575	0,578517937	0,538845074	0,506806185
1100	1	0,999473218	0,97430308	0,900491241	0,81220827	0,732547154	0,666719203	0,613565617	0,570633669	0,535649069
1200	1	0,999862566	0,985722135	0,928593787	0,848705405	0,770722876	0,70344144	0,647710088	0,601970491	0,564305745
1300	1	0,999968327	0,992470465	0,950163379	0,880148706	0,805635407	0,738190569	0,680703353	0,632662714	0,592628559
1400	1	0,999993558	0,996233839	0,966186325	0,906676631	0,8371025	0,770722876	0,712324238	0,662529707	0,620475049
1500	1	0,999998845	0,99821433	0,977706176	0,928593787	0,865054516	0,800855845	0,742382683	0,691406196	0,647710088
1600	1	0,999999817	0,999197849	0,985722135	0,946326326	0,889525466	0,828469578	0,770722876	0,719144957	0,674207837
1700	1	0,999999975	0,999658748	0,991120573	0,960375909	0,910639429	0,85350555	0,797225136	0,745618951	0,699853472
1800	1	0,999999997	0,999862566	0,994639293	0,971276791	0,928593787	0,875962972	0,821806546	0,770722876	0,724544627
1900	1	1	0,999947619	0,996859049	0,979559372	0,943640832	0,895893164	0,844420395	0,794374098	0,748192539
2000	1	1	0,999981112	0,99821433	0,985722135	0,95606919	0,913392406	0,865054516	0,816512958	0,770722876
2100	1	1	0,999993558	0,999015193	0,990212596	0,966186325	0,928593787	0,883728683	0,8371025	0,792076227
2200	1	1	0,999997922	0,999473218	0,993416741	0,97430308	0,941658595	0,900491241	0,856127642	0,81220827
2300	1	1	0,999999366	0,999726746	0,995655664	0,980720915	0,952767702	0,91541517	0,873593859	0,831089624
2400	1	1	0,999999817	0,999862566	0,99718771	0,985722135	0,962113393	0,928593787	0,889525466	0,848705405
2500	1	1	0,99999995	0,999932988	0,99821433	0,989563136	0,969891962	0,940136298	0,903963566	0,865054516
2600	1	1	0,999999987	0,999968327	0,998888011	0,992470465	0,976297332	0,950163379	0,916963773	0,880148706
2700	1	1	0,999999997	0,99998549	0,999320927	0,994639293	0,981515822	0,958802958	0,928593787	0,894011443

Figure 37: First 10 years of distribution of variation in daily car users due to increase in use of autonomous vehicles

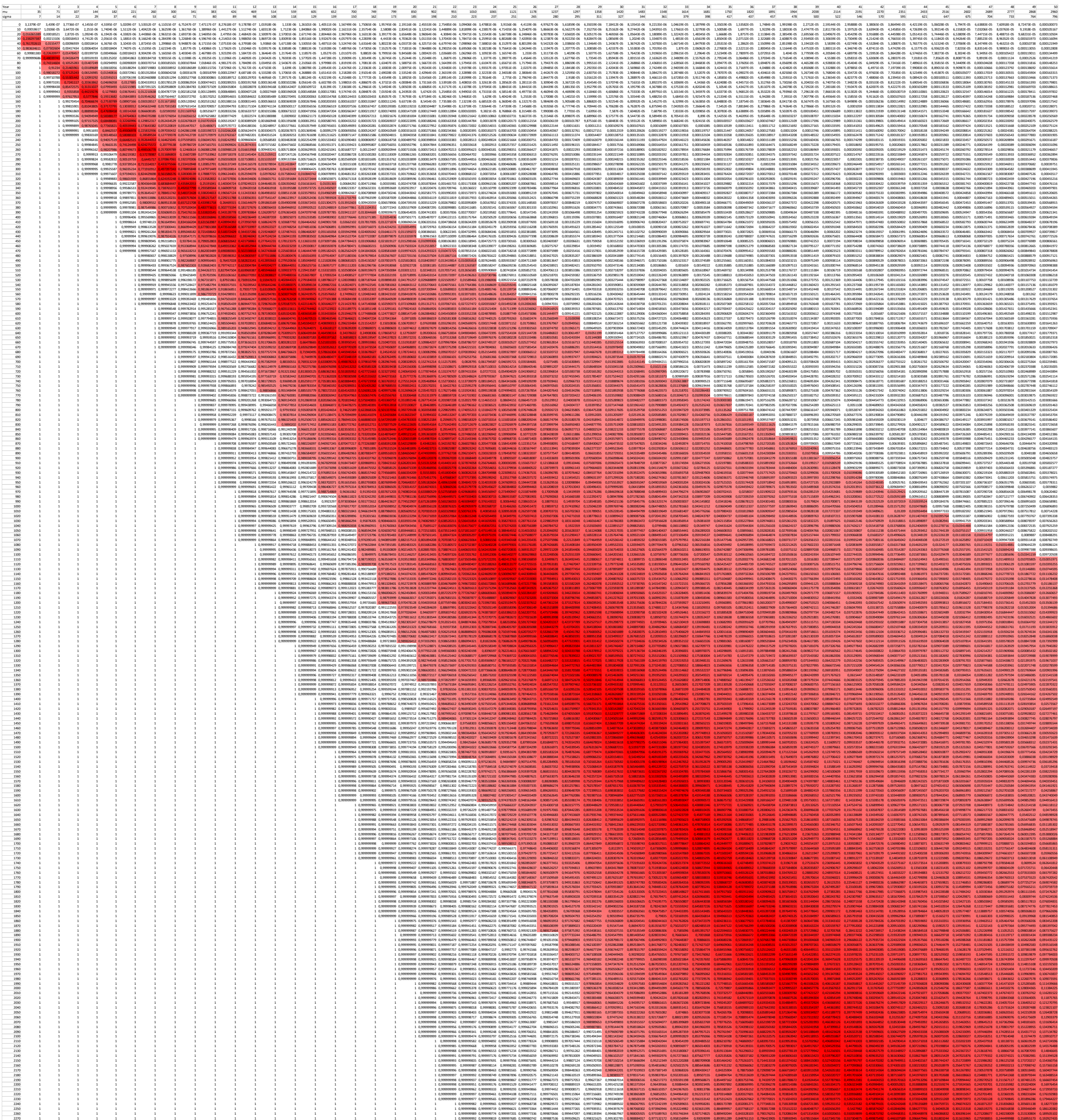

Figure 38: Distribution of additional daily bike users due to increase in hybrid bikes

Year	1	2	3	4	5	6	7	8	9	10
mu	35	71	107	144	182	221	260	300	341	383
sigma	7	14	22	29	37	45	53	62	71	80
0	3,1379E-07	3,439E-07	3,7736E-07	4,1455E-07	4,5595E-07	5,0209E-07	5,53552E-07	6,11015E-07	6,75247E-07	7,47117E-07
10	0,00018617	1,0106E-05	3,6472E-06	2,251E-06	1,7404E-06	1,5112E-06	1,40422E-06	1,36259E-06	1,36176E-06	1,38996E-06
20	0,016365389	0,00018521	2,872E-05	1,0924E-05	6,1942E-06	4,3382E-06	3,44386E-06	2,96321E-06	2,69373E-06	2,54695E-06
30	0,238297387	0,00213106	0,00018453	4,7412E-05	2,0561E-05	1,1881E-05	8,16624E-06	6,28439E-06	5,22684E-06	4,59674E-06
40	0,761702613	0,0155477	0,00096939	0,00018414	6,3676E-05	3,1043E-05	1,87245E-05	1,29986E-05	9,94887E-06	8,17155E-06
50	0,983634611	0,07302604	0,00417434	0,00064054	0,00018404	7,7407E-05	4,15195E-05	2,62234E-05	1,8577E-05	1,43086E-05
60	0,99981383	0,22620977	0,01478457	0,00199759	0,00049666	0,00018423	8,90429E-05	5,16026E-05	3,40304E-05	2,46798E-05
70	0,999999686	0,48039741	0,04326479	0,00559193	0,00125202	0,00041863	0,000184718	9,90555E-05	6,11598E-05	4,19325E-05
80	1	0,74314604	0,10525283	0,01407249	0,00294993	0,00090839	0,000370714	0,000185501	0,000107844	7,01846E-05
90	1	0,91234	0,21465961	0,03189689	0,00650056	0,00188294	0,000719883	0,000338932	0,000186589	0,000115726
100	1	0,98018272	0,37125243	0,06526985	0,01340816	0,00372961	0,001352854	0,000604258	0,00031678	0,00018799
110	1	0,99710788	0,55301442	0,12093292	0,02591013	0,00706198	0,002460888	0,001051294	0,000527768	0,000300865
120	1	0,99973191	0,7241117	0,20363862	0,04696058	0,0127885	0,004333913	0,001785129	0,000862924	0,000474421
130	1	0,99998438	0,85472575	0,31311027	0,07993493	0,02215985	0,007391325	0,002958809	0,001384783	0,000737109
140	1	0,99999943	0,9355858	0,44219276	0,1279883	0,03676441	0,012210638	0,004787729	0,002181258	0,001128495
150	1	0,99999999	0,97617953	0,5777846	0,19313682	0,05843893	0,019546262	0,007564467	0,003372792	0,00170252
160	1	1	0,99270454	0,70466674	0,27530789	0,08907166	0,030328517	0,011671892	0,005120042	0,002531262
170	1	1	0,99815901	0,81043805	0,37172791	0,13030012	0,045632448	0,017591583	0,007631454	0,003709057
180	1	1	0,99961869	0,88898594	0,47698458	0,18314268	0,066608185	0,02590392	0,011169763	0,00535677
190	1	1	0,99993536	0,94094949	0,58388177	0,24764063	0,094370288	0,037276054	0,016056152	0,007625882
200	1	1	0,99999105	0,97157325	0,68488081	0,32260996	0,129852317	0,052434529	0,022670619	0,010701924
210	1	1	0,99999899	0,98765045	0,77365821	0,40559443	0,173643382	0,072120819	0,031447017	0,01480671
220	1	1	0,99999991	0,9951693	0,8462557	0,49306978	0,225832936	0,097030432	0,042861398	0,020198723
230	1	1	0,99999999	0,99830169	0,90148563	0,58088103	0,28589534	0,127739378	0,057412739	0,027170979
240	1	1	1	0,99946416	0,94057519	0,66482515	0,352644053	0,164625045	0,075595855	0,036045765
250	1	1	1	0,99984845	0,9663135	0,74124498	0,424275572	0,20779138	0,09786729	0,047165755
260	1	1	1	0,99996162	0,98207986	0,80749673	0,498506778	0,257009789	0,12460614	0,060881298
270	1	1	1	0,9999913	0,99106479	0,86219382	0,57278987	0,311686803	0,15607289	0,077533962
280	1	1	1	0,99999824	0,99582832	0,90519759	0,6445717	0,370867061	0,192370306	0,097436867
290	1	1	1	0,99999968	0,9981778	0,93739524	0,711554017	0,433275566	0,233410948	0,120852791
300	1	1	1	0,99999995	0,99925587	0,96035234	0,771910912	0,497397343	0,278895848	0,147971449
310	1	1	1	0,99999999	0,99971607	0,97594015	0,824429698	0,561586576	0,328308139	0,178887725
320	1	1	1	1	0,99989883	0,98601939	0,86855864	0,624192248	0,380924086	0,213582832
330	1	1	1	1	0,99996635	0,99222587	0,904364438	0,683684447	0,435842053	0,25191041
340	1	1	1	1	0,99998956	0,99586533	0,932419045	0,738765372	0,492027799	0,293589344
350	1	1	1	1	0,99999698	0,99789771	0,953645427	0,788451742	0,548372428	0,338204653
360	1	1	1	1	0,99999918	0,99897851	0,969153886	0,832120231	0,603757604	0,385217147
370	1	1	1	1	0,99999979	0,99952585	0,98009552	0,869513538	0,657121708	0,433981758
380	1	1	1	1	0,99999995	0,99978981	0,987549986	0,900710652	0,707520434	0,483773615
390	1	1	1	1	0,99999999	0,99991104	0,992454224	0,926069515	0,754176116	0,533820145
400	1	1	1	1	1	0,99996406	0,995569865	0,946153039	0,796511566	0,583336846
410	1	1	1	1	1	0,99998614	0,99748123	0,961649941	0,834166204	0,631563987
420	1	1	1	1	1	0,9999949	0,998613528	0,973300441	0,866994429	0,677801388
430	1	1	1	1	1	0,99999821	0,999261264	0,981834173	0,895048182	0,721438642
440	1	1	1	1	1	0,9999994	0,999619076	0,987924326	0,918547171	0,761978616
450	1	1	1	1	1	0,99999981	0,999809945	0,992158923	0,93784116	0,799052803
460	1	1	1	1	1	0,99999994	0,999908262	0,995027659	0,953368944	0,832427848
470	1	1	1	1	1	0,99999998	0,999957167	0,996921153	0,965618253	0,862003489
480	1	1	1	1	1	1	0,999980657	0,998138829	0,97508996	0,887802828
490	1	1	1	1	1	1	0,999991553	0,998901775	0,982268887	0,909956465
500	1	1	1	1	1	1	0,999996433	0,999367524	0,987602303	0,928682403
510	1	1	1	1	1	1	0,999998544	0,999644538	0,991486185	0,944263721
520	1	1	1	1	1	1	0,999999425	0,999805066	0,99425849	0,95702596
530	1	1	1	1	1	1	0,999999781	0,999895699	0,996198172	0,967315871
540	1	1	1	1	1	1	0,999999919	0,999945556	0,997528427	0,975482794
550	1	1	1	1	1	1	0,999999971	0,999972277	0,998422666	0,981863479
560	1	1	1	1	1	1	0,99999999	0,99998623	0,999011899	0,986770729
570	1	1	1	1	1	1	0,999999997	0,999993329	0,999392469	0,990485836
580	1	1	1	1	1	1	0,999999999	0,999996848	0,999633402	0,993254474
590	1	1	1	1	1	1	1	0,999998548	0,999782914	0,995285537
600	1	1	1	1	1	1	1	0,999999347	0,999873856	0,996752241

Figure 39: First 10 years of distribution of additional daily bike users due to increase in hybrid bikes